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INNOVATION AND AMERICA'S INFRASTRUCTURE: EXAMINING THE EFFECTS OF EMERGING AUTONOMOUS TECHNOLOGIES ON AMERICA'S ROADS AND BRIDGES

HEARING

BEFORE THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS UNITED STATES SENATE

ONE HUNDRED FIFTEENTH CONGRESS

SECOND SESSION

JUNE 13, 2018

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COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

ONE HUNDRED FIFTEENTH CONGRESS
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C O N T E N T S

INNOVATION AND AMERICA'S INFRASTRUCTURE: EXAMINING THE EFFECTS OF EMERGING AUTONOMOUS TECHNOLOGIES ON AMERICA'S ROADS AND BRIDGES

WEDNESDAY, JUNE 13, 2018

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, DC.

The Committee met, pursuant to notice, at 10:06 a.m. in room 406, Dirksen Senate Office Building, Hon. John Barrasso (Chairman of the Committee) presiding.

Present: Senators Barrasso, Carper, Capito, Wicker, Fischer, Rounds, Ernst, Sullivan, Cardin, Merkley, Gillibrand, Booker, Markey, and Van Hollen.

OPENING STATEMENT OF HON. JOHN BARRASSO, U.S. SENATOR FROM THE STATE OF WYOMING

Senator BARRASSO. Well, good morning. I call this hearing to order.

Today we are going to examine the implications of emerging technologies of America's roadway infrastructure.

Last month our Committee unanimously passed bipartisan legislation to approve America's water infrastructure. We are now working together to pass America's water infrastructure act on the Senate floor. I believe this bipartisan success on water infrastructure is going to lead to bipartisan success on America's surface transportation infrastructure, namely, legislation to address our roads and our bridges.

We are planning to build infrastructure that will last for decades. We need to understand the new challenges that those decades will bring to all of us. The ongoing development and implementation of autonomous vehicles and connected vehicles and other innovations have the potential to fundamentally change the way our Nation's infrastructure works.

Autonomous vehicles will likely require modification to our roadways and changes to the practices of Federal, State, and local transportation agencies. It is critical that State and Federal transportation agencies are prepared and equipped to tackle the potential opportunities and challenges they present for our roads. Those agencies will need to develop, install, and maintain traffic control devices in such a way that they are understood and obeyed by motorists, as well as autonomous vehicles.

As autonomous vehicles become more common on the road, they could influence regional traffic models and forecasts. They will also add new factors as agencies make long-term planning decisions. At the same time, new vehicles technologies offer many potential benefits and could transform the way that we view surface transportation altogether.

Soon, elderly and disabled Americans, as well as those without a car of their own, may be able to travel by vehicle with greater ease and greater independence. Likewise, these innovations have great potential to reduce crashes and fatalities, to improve mobility, and to increase the efficiency of the roadway system. How their benefits are realized will depend on industry and agencies working together to make sure that our roads keep pace with the vehicles that they accommodate.

An excellent example of infrastructure innovation is happening in my home State of Wyoming. The Wyoming Department of Transportation is implementing a Connected Vehicle Pilot program to improve monitoring and reporting of road conditions on Interstate 80. Projects like these are vital for the future of our Nation's roadway infrastructure.

So, I am glad that Bill Panos, the Wyoming Director of the Department of Transportation, is here to tell us more about that project and other work being done in his department.

I also want to thank all of the other witnesses for participating in today's hearing. Your expertise and insight will help us understand potential high tech challenges and opportunities for our Nation's roadway infrastructure.

Senator Carper is unavoidably delayed; he will be here shortly, and he will make his full opening statement at that time.

So, I want to thank all of you for being here.

I am pleased to welcome Bill Panos, who has served as the Director of the Wyoming Department of Transportation. He is a graduate of California State University, where he received a degree in forensic science and technology. Before moving to Wyoming, he accrued 37 years of experience leading private and public service organizations. He has also served as the Director of the Wyoming School Facilities Department.

Joining Bill today in testifying will be Mr. Shailen Bhatt, who is the President and CEO of the Intelligent Transportation Society of America; Mr. Zachary Doerzaph, who is the Director of the Center for Advanced Automotive Research; Polly Trottenberg, who is the Commissioner for the New York City Department of Transportation; and Shaun Kildare, the Director of Research at Advocates for Highway and Auto Safety.

I want to remind the witnesses that your full written testimony will be made part of the official hearing record today, so please keep your statements to 5 minutes so that we will have time for questions. I look forward to hearing the testimony from each of you.

With that, we will begin with Mr. Panos. Appreciate your being here.

STATEMENT OF WILLIAM "BILL" PANOS,
DIRECTOR, WYOMING DEPARTMENT OF TRANSPORTATION

Mr. PANOS. Chairman Barrasso and members of the Committee, I am Bill Panos, Director of the Wyoming Department of Transportation. I am here today on behalf of WYDOT and AASHTO.

The Committee's premise in holding this hearing is correct; connected and automated vehicles have implications for highway infrastructure. In addressing those infrastructure issues, safety is a top priority for State DOTs. That includes attention to striping and signage, as well as to more complex issues. Collaboration between technology developers, vehicle manufacturers, and government agencies is important. This includes working to ensure interoperability of systems so that deployment of dedicated short range communications, or DSRC, along the highway system will be effective. Let me elaborate.

These new technologies have the potential to reduce crashes, save lives, and provide other benefits. However, there is still uncertainty surrounding these innovative technologies, including infrastructure related issues. For example, for there to be highway infrastructure, work zones on the roads are inevitable. How will an automated driving system, or ADS, get by work zones? What are the specific signage and striping needs? What advisories from DSRC enabled infrastructure would help connected and autonomous vehicles and improve safety?

State DOTs are preparing for deployment of CAVs by, among other things, starting to plan and deploy relevant technology as part of the highway infrastructure, and these investment needs are near term, in part because a connected vehicle need not be an automated vehicle. Cars driven by people are increasingly equipped with electronics that can receive data from DSRC enabled equipment along the roadway. DSRC signals can help non-automated, as well as automated, vehicles effectively "see" in bad weather, provide other information, such as on traffic congestion.

State and local agencies are active in deploying and testing these systems today. Approximately 50 U.S. locations are deploying connected vehicle technologies. This represents roughly 72,000 vehicles and 65,000 devices installed on the Nation's infrastructure. WYDOT is an active participant.

To improve safety along the 402 miles of Interstate 80 in Wyoming, particularly in our tough winters, Wyoming is implementing a pilot program using DSRC enabled technology to connect vehicles to infrastructure and to other vehicles. During Federal fiscal year 2016 more than 1,600 crashes occurred on I–80 in Wyoming, resulting in 18 fatalities and 271 injuries. In December 2016 there were only 8 days when I–80 in Wyoming was fully open.

As part of the effort to improve the situation, the pilot program will test warnings advising travelers of crashes ahead. It will also advise about weather, speed restrictions, work zones, and other matters. Testing with WYDOT vehicles occurred last winter, and we will be testing commercial freight vehicles this winter.

Let me turn to a few more points on the infrastructure implications of CAV deployment.

Currently State DOTs are unsure which roadway elements are critically important to automated driving system, or ADS, tech-

nology. We know that quality signage and striping are important, but welcome more details. In most cases, striping is a maintenance, not a capital, activity. Similarly, sign maintenance is not a capital activity.

All other things being equal, an increase in maintenance costs would reduce funding available for capital investments in transportation, so we want to understand the maintenance implications of CAV deployment. In addition, if ADS equipped vehicles have sensors that could be adversely impacted by poor ride quality, that could place upward pressure on already high needs for investments to maintain and improve pavement ride quality.

There are additional issues where State DOTs want to better understand what type of information would help all CAVs.

Deployment of ADS technology in rural environments also raises issues. For example, DSRC enabled infrastructure on long rural highways would be costly. This suggests different solutions for advisories in very rural areas, such as cellular technology, at least where there is adequate cell phone service. In any event, we want vehicles to have access to weather, crash, and other key advisory information. It seems that we have to put technology into the infrastructure to do that.

So, when a State DOT talks about interoperability, it is not to tell a developer how to equip a vehicle. Simply, if a State is deciding whether to use scarce infrastructure dollars to deploy DSRC enabled systems, it wants to know that the investment in DRC can successfully communicate advisory information to vehicles.

In conclusion, Mr. Chairman, CAVs are arriving and are in our future. We want the infrastructure to be safer than it has ever been when they are deployed. States are eager to work hard toward those ends.

Thanks for the opportunity to appear before the Committee today.

[The prepared statement of Mr. Panos follows:]

William T. "Bill" Panos
Director, Wyoming Department of Transportation
Cheyenne, Wyoming

William T. "Bill" Panos was appointed the 17th Director of the Wyoming Department of Transportation in October 2015. Director Panos came to Wyoming with impressive credentials, drawing from diverse experience he's gained working in both the private and public sectors over the past 37 years.

Bill is a native of California and a graduate of the California State University where he studied physics and forensic science. His previous work has included engineering and leadership positions with the TRW Corporation, the Commonwealth of Massachusetts, the State of Washington and local government. Immediately prior to heading the state's transportation agency, he was director of Wyoming's School Facilities Department for two years.

Bill also plays a leadership role in transportation issues for the United States. Bill serves on the American Association of State Highway Transportation Officials (AASHTO) Board of Directors and the Western Association of State Transportation Officials (WASHTO) Board of Directors. Previously he served as Director for the Port of Sacramento, Advisor to the President's Council on Sustainable Development, and Special Advisor to the Chancellor of the California State University System.

During his career, his work has intersected with numerous transportation-related functions and issues, including transportation safety, automotive manufacturing, government reform, infrastructure development, capital finance and asset management, public policy and regulation, multi-site operations, advanced risk assessment, and inter-agency relations.

AMERICAN ASSOCIATION
OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS

AASHTO

TESTIMONY OF

The Honorable William T. "Bill" Panos
Chair, Committee on Transportation System Operations, American Association of State Highway and Transportation Officials;
Director, Wyoming Department of Transportation

REGARDING

Deployment of Connected and Automated Vehicles; Implications for Highway System Infrastructure

BEFORE THE

Committee on Environment and Public Works of the United States Senate

ON

June 13, 2018

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INTRODUCTION

Chairman Barrasso, Ranking Member Carper, and Members of the Committee, thank you for the opportunity to appear today and address implications for our highway infrastructure from deployment of connected and automated vehicles (CAVs).

My name is Bill Panos, and I serve as Director and CEO of the Wyoming Department of Transportation (WYDOT) and as Chair of the Committee on Transportation System Operations of the American Association of State Highway and Transportation Officials (AASHTO). I appear today on behalf of Wyoming and AASHTO, which represents the state departments of transportation (state DOTs) of all 50 States, Washington, D.C., and Puerto Rico.

I became Director of WYDOT in 2015 after 37 years leading private and public sector organizations, including engineering and leadership positions with the TRW Corporation, the Commonwealth of Massachusetts, the State of Washington, and local government.

Our testimony today emphasizes the following points, beginning with safety:

- Safety has been and always will be the ultimate priority for state DOTs, including as they invest in and manage infrastructure relating to CAV deployment;
- Both connected and automated vehicles are in our future;
- The highway infrastructure investment implications of deploying connected and automated vehicles must be recognized and addressed, including by ensuring that capital investments in infrastructure related to CAVs are eligible uses of funds under the Federal-aid highway program;
- Nationwide interoperability, including further deployment of Dedicated Short Range Communications (DSRC), is essential;
- We should achieve increased collaboration between technology developers, vehicle manufacturers, and federal, state and local agencies; and
- More federal resources should be provided for research in this area.

SAFETY HAS BEEN AND ALWAYS WILL BE THE ULTIMATE PRIORITY FOR STATE DOTS, INCLUDING AS THEY INVEST IN AND MANAGE HIGHWAY INFRASTRUCTURE RELATING TO CAV DEPLOYMENT

Safety is the most important consideration for AASHTO and state DOTs respecting highway infrastructure and the emerging deployment of CAVs. These new technologies have the potential to decrease crashes and fatalities significantly and positively influence the safety of not only vehicle occupants, but also highway maintenance and construction workers, bicyclists, and pedestrians. While the prospect for safety improvement is exciting, we are also acutely aware that this is truly innovative technology and there are still uncertainties surrounding it. Attention to safety is, of course, part of the discussion. Today we are focusing on these developments as they relate to infrastructure, including investments in infrastructure.

So, there are a wide range of issues related to CAV deployment and infrastructure to consider. Inherent in having infrastructure is that it has to be built, which means there are highway construction zones. So, among the questions highway owners are considering are:

- How will an automated driving system (ADS) navigate a temporary work zone?
- How will it handle variable speed limits (speed limits are frequently reduced in construction zones)?
- There are many other issues, including issues concerning fleets with mixed automation capabilities. Some of the more frequently raised issues are:
    - What are the signage and striping issues?
    - What advisories from DSRC enabled infrastructure would be helpful to automated vehicles and improve safety?

A better understanding of how these systems work, and the results of on-road testing showing how ADS equipped vehicles sense and respond to non-ADS equipped vehicles, would provide infrastructure agencies with useful information about how to plan infrastructure for the future. State DOTs are ready and willing to work with all stakeholders in addressing such safety issues.

But while noting these technical issues, we have not lost sight of the potential for these vehicles reduce crashes and fatalities, perhaps greatly.

BOTH CONNECTED AND AUTOMATED VEHICLES ARE IN OUR FUTURE; WHAT STATES ARE DOING NOW

There are many reasons why we are anticipating deployment of these innovative technologies. One is simply the outstanding capacity and innovative capabilities of many people in many companies. Others include consumer demand and the potential for increased safety, as human error is a factor in so many crashes. Also, many that are less mobile, such as senior citizens and people with disabilities, see CAVs as a tremendous boost to their mobility and quality of life. So, for a variety of reasons, the deployment is coming.

As the owners of a significant amount of the highway transportation infrastructure, state DOTs are at the forefront of preparing for deployment of CAVs, including ensuring that the current infrastructure is in a state of good repair such that any vehicle can operate on it in a safe and effective manner. In addition, many state DOTs are starting to plan, design, deploy, operate, and maintain the technology needed for CAVs, including vehicles equipped with ADS and vehicles connected to each other and the infrastructure.

For those who may be skeptical that investment needs in this area are growing, let me emphasize that a connected vehicle need not be an automated vehicle. Cars that are being driven by people are increasingly connected and equipped with electronics that can receive data from DSRC enabled equipment installed in or near the roadway. Such signals help a vehicle "see" in the snow or fog and provide other information. We can develop and deploy roadside infrastructure that can assist both ADS equipped vehicles and increasingly advanced non-ADS equipped vehicles.

AASHTO's member DOTs believe that establishing a strong foundation for CAVs requires robust connectedness for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. The overwhelming support for the development and deployment of connected vehicle technologies is evident in the significant commitment that the states and local agencies have made in leading, supporting, and fostering the deployment and testing of CAV systems. To date, 33 locations in the US, including in my home state of Wyoming, are deploying connected vehicle technologies under sponsorship of the United State Department of Transportation (USDOT), and 17 locations are deploying the technologies without sponsorship from USDOT. Combined, this represents 72,000 vehicles on the road and 65,000 devices installed on the infrastructure.

Let me illustrate further by discussing an example.

In Wyoming, to improve safety along the 402 miles of Interstate 80 in my state, the Wyoming Department of Transportation is implementing a USDOT pilot program using DSRC enabled technology to connect vehicles to infrastructure and to other vehicles.

This corridor along the southern section of Wyoming is prone to winter crashes affecting both commercial and private vehicles. It is subjected to some of the most extreme winter weather conditions—especially blowing snow and vehicle blow overs—of any highway on the U.S. interstate system. From October 2015 to September 2016, more than 1,600 crashes occurred on I-80 in Wyoming, resulting in 18 fatalities and 271 injuries. During this period, all or parts of I-80 were closed to all vehicles for a total of over 1,500 hours—impacting not only travelers but also the trucks that make up roughly 55 percent of the state's total annual traffic stream and carry more than 32 million tons of freight across the state each year.

The Wyoming pilot program will test applications, such as advanced forward collision warnings, to let travelers know of crashes ahead. It will also provide: immediate situational awareness warnings about weather alerts, speed restrictions, parking availability, and so forth; detailed and

current work zone warnings; specialized spot weather impact warnings for ice, fog, and other hazards; and notifications from disabled vehicles.

Pilot testing with WYDOT vehicles such as highway patrol cars and snowplows occurred last winter. We will analyze this season's data, and test with commercial vehicles next winter. Other sites under the federal pilot program will test hot, humid weather (Tampa, Florida) and congestion (New Jersey/New York City) applications.

INFRASTRUCTURE INVESTMENT IMPLICATIONS OF DEPLOYING CONNECTED AND AUTOMATED VEHICLES MUST BE RECOGNIZED AND ADDRESSED

We turn now to the infrastructure implications of the emerging deployment of CAVs.

Currently, state DOTs (and other infrastructure owners) are uncertain, at least at a detailed level, which roadway characteristics are critically important to the safe and efficient operation of ADS. Aspects of ADS have been developed in the absence of significant collaboration between the infrastructure owners and technology developers. Thus, state DOTs want a clearer consensus on infrastructure needs from the technology developers.

We know some of the developers' needs in a general way. Industry has filed comments at USDOT that signage and lane marking and striping are important. One state has responded to this concern by going from 4-inch to 6-inch stripes to help the technology developers with their sensors and lane departure warning systems. Other states, however, are not as willing to modify their lane striping widths because this is seen as a major investment. They may, however, stripe more frequently, to maintain visibility. In most cases striping is a maintenance activity, not a capital activity eligible under the Federal highway program.

However, any increase in maintenance would not be without implications for a state DOT's or other transportation agency's overall budget and its ability to make other needed infrastructure investments. In these scenarios, there would be less available for capital expenditures on transportation infrastructure.

Further underscoring our interest in working with the developers, it is not clear how critical lane striping is to ADS, as many systems are not dependent upon them. Further, the relevance of striping may be limited in environments that are not ideal such as construction zones or when snow or ice obscures the lines.

Beyond striping, if ADS equipped vehicles have sensors that could be adversely impacted by poor or intermittent ride quality, that could place upward pressure on the already high need for investment in maintaining and improving pavement quality.

While respecting the developers' abilities to work to address CAV operations within today's infrastructure, AASHTO recommends and strongly desires more collaborative dialogue between the infrastructure owners and the technology developers as to infrastructure. This dialogue would

include work to better define the roadway characteristics and infrastructure elements that are critical to the efficient and safe deployment of CAVs. One approach would be to discuss and publish a list of existing data on roadway characteristics that the state DOTs can readily provide to the technology developers. This list will help the technology developers with near-term ADS applications and encourage them to identify additional data that they will need to successfully develop ADS. The state DOTs need consensus from the technology developers about what data and information is needed and that it be consistent among all technology developers. Otherwise, the state DOTs are continuing to chase the technology requirements.

In addition, there has been discussion about the consistent application of the FHWA Manual on Uniform Traffic Control Devices (MUTCD) and its ability to provide consistency throughout the United States. While conformance to MUTCD already takes place, many states and localities provide exceptions to the MUTCD for various reasons. Strict adherence to the MUTCD may be desirable from the perspective of ADS developers, but the reality is that there will always be exceptions that must be accounted for. In addition to these exceptions, there will also be instances of storms or incidents knocking down and damaging signage along the roadway, and snow and debris can obscure lane stripes. State DOTs aim to repair and replace damaged signs and striping as quickly as possible, but may not be able to do so on a timeline needed by technology that relies on signage and striping alone for ADS operations.

Another priority is the deployment of ADS and more robust connected vehicle infrastructure in rural environments. State DOTs and many counties own the rural highways which, due to their longer routes, need different solutions, such as more reliance on cellular technology. As there are rural areas of the nation that still do not have adequate cell phone service, we need to ensure rural connectivity in deployment of CAVs.

We view the potential highway capital costs associated with CAV deployment, such as V2I and related signage, as already eligible uses of a state's apportioned funds under the Federal-aid Highway Program. However, to the extent that any type of highway capital cost related to servicing CAVs comes to the attention of the Committee as not eligible under the current program, the additional eligibility should be provided.

State DOTs are committed to maintaining their assets in as good a condition as possible given the resources available to them. At this point, state DOTs do not know what, or if, minimum conditions are needed for ADS to operate effectively or what the minimum condition levels should be. The state DOTs look forward to working with other public and private sector partners in updating the practical meaning of state of good repair in a world of deployed CAVs.

As noted earlier, providing alerts to CAVs as to weather, traffic, work zones and other advisories has implications for investment in DSRC enabled equipment deployments as part of the infrastructure. Simply put, because we want our vehicles to have such information, we will need to invest to make that possible.

And, importantly, there are potential savings from deployment of CAVs. Some see the potential for narrower lanes or shoulders, for example, due to more precise driving by ADS vehicles.

Also, there is the potential for improved throughput. ADS equipped vehicles may need shorter separation between vehicles. CAVs may also be able to take better advantage of improved traffic light technology to improve vehicle throughput. More specifically, AASHTO is supporting a national traffic signal phasing and timing (SPaT) program that heavily leverages V2V and similar technologies to improve traffic flow and reduce crashes. Through the SPaT Challenge, AASHTO is hoping to achieve the deployment of V2I infrastructure with SPaT broadcasts at roadway intersections in at least one corridor or network in each of the 50 states and Washington, DC by January 2020. Individual states are also working to comprehensively improve traffic signals in similar ways.

NATIONWIDE INTEROPERABILITY, INCLUDING FURTHER DEPLOYMENT OF DEDICATED SHORT RANGE COMMUNICATIONS, IS ESSENTIAL

In general, state DOTs see significant benefits—in both directions—from sharing with developers detailed digital maps and dynamic traffic information such as alerts about nearby vehicles, pedestrians and bicyclists, weather, and lane availability associated with incidents and construction projects. To achieve these benefits would involve the two-way exchange of data between the vehicles and infrastructure. Some of the data discussions needed to achieve this are going on through the development of Society of Automotive Engineers (SAE) standards, the Connected Vehicle Pooled Fund Study, and the V2I Deployment Coalition.

Information exchange must address connectivity between the vehicles and the roadside infrastructure. Without the digital infrastructure and data, ADS operability that is reliant on information from roadside equipment would essentially become non-functional. AASHTO believes that vehicle connectivity enhances and expands the safety and mobility benefits of ADS by providing information that the vehicle sensors cannot "see" and important redundancy of information that the sensors can "see." When dealing with life-safety issues, redundancy can be a solution, not a problem.

In discussing some of the technical aspects of interoperability, let me note that our purpose is not to comment on vehicle-specific issues, but to describe the background against which a state or other infrastructure owner would decide to make an infrastructure investment by deploying DSRC enabled equipment along a road.

Digital infrastructure at its basic level includes the hardware and software associated with applications and communications, and is typically identified as being either on-board equipment if it's contained within the vehicle or road side equipment if it exists as part of the roadway network. Both applications and communications can be defined to exist in environments described as isolated (i.e., a remote roadside weather information system), local (i.e., signal system on a corridor), area wide (i.e., capturing vehicle responses in adverse driving conditions such as activating windshield wipers or having automatic braking systems engaged and sharing that information with other vehicles or roadside units within a designated area), regional (cellular wireless access, sharing traveler information) or even global (GPS) infrastructure.

This digital infrastructure serves as the conduit by which data can be consumed and acted upon by the ADS. So, standards for both infrastructure and vehicle would make this work, especially when dealing with different original equipment manufacturers.

Two interfaces for V2I information transfers are available today: 4GLTE for non-time-critical data and dedicated short range communication (DSRC) for low-latency applications. We believe both approaches need to be leveraged, and both should use the same data definitions and standards in SAE J2735. The challenge with cellular data, to date, has been that most of the transmissions have been through corporate-specific clouds (generally not open to data sharing between various manufacturers) and are based on a fee-for-service arrangement, limiting the data to those willing and able to pay the fee. We believe this is not the appropriate model to facilitate broad increases in safety for all users.

The advantage of DSRC is that it is very fast, which is essential for many safety applications, and is fee-free. We applaud the USDOT for spending considerable effort developing, testing, and proving the DSRC medium, including encouraging its use in many test beds and deployments. Because of its benefits, we encourage a continuation of support for this medium. While other mechanisms, such as 5G, promise great advantages, we encourage the USDOT to require that those data transmissions be company-agnostic (available to all vehicle brands and types), free from user fees, and fully backwards compatible with current messages. If this is not the case, safety benefits will be limited, and the large investments currently being made by government in available technologies will be diminished. So, we see interoperability across technologies as essential.

Regarding data transmission, it should be in a format that can be easily consumed on multiple fronts for sharing without any need for translation. In the scenario where the on board equipment provides information to the road side equipment, that information should be easily translated to other potential users or applications (i.e., traffic operations centers or advanced traffic management systems). Beyond data format, specific kinds of information that would enhance safe and efficient operations would include those associated with service packages identified in the national architecture, such as weather, construction, maintenance, road conditions, and advisories.

While we believe accelerating ADS deployment would best be determined by the system developers, it would be helpful to infrastructure owners to have in advance of deployment a solid understanding of an ADS operation design domain. For example, if the relationship between the algorithms and the mechanical systems controlling the dynamic driving functions has operational limits (i.e., can't assume steering control at certain speeds and/or under certain road conditions or terrain), that should be shared with other users so they too would know when they're approaching being beyond their respective design limits well in advance of it occurring. More collaboration among public sector agencies and private sector developers would better address this.

In terms of types of operations data needed by ADS, there are numerous examples, including roadway characteristics (pavement type, geometric design, condition), signal phasing and timing, work zone information (when, where, duration, type), incidents information, weather conditions, and current traffic characteristics (speed, volume, type).

On the other hand, ADS could provide valuable transportation planning data, such as ridership, occupancy, origin/destination, and, potentially, roadway maintenance data (pavement/paint/sign condition). If original equipment manufacturers were able to provide this type of information at the individual vehicle level, state DOTs may be able to redirect significant resources for other purposes such as better maintaining the infrastructure rather than data collection.

To elaborate, a significant amount of variable information and data could be provided to ADS by state DOTs. But it needs to be done in a way that connects effectively to the vehicle. For example:

- Is it enough to know the beginning and end of work zone location or does it also need to include more data due to construction or maintenance activities? For example, work zone configuration can change multiple times in a day and can be affected by weather conditions.
- How much information does the vehicle need and how detailed is that information? This also has implications for setting up and operating work zones.
- For weather-related roadway impacts such as standing water, snow, and wind impacts, how much detail must be provided to an ADS vehicle?
- As to vertical or horizontal limitations such as low bridges and temporary wire crossings, how would the infrastructure best provide that information?

State DOTs need to understand the data needs of the ADS and how to provide data in a consistent format, frequency and reliability that meets the needs of ADS. However, with hundreds of thousands of lane miles to cover, providing fast, up-to-date data can be an expensive, technical challenge.

State DOTs support nationwide interoperability while still maximizing flexibility and cost effectiveness for ADS technology developers and transportation agencies and minimizing threats to cybersecurity and/or privacy. In general, maximizing flexibility and cost effectiveness must include a consideration for standards that are open source (allowing for improvements), as well as establishing data definitions and associated priorities of those definitions, and identifying what's needed for operational functionality and what's not needed.

ACHIEVE INCREASED COLLABORATION BETWEEN TECHNOLOGY DEVELOPERS, VEHICLE MANUFACTURERS, AND FEDERAL, STATE AND LOCAL AGENCIES

Infrastructure owners and operators want more information from the automakers about what infrastructure elements they need in order to be successful. The advent of ADS and connected technology represents a new paradigm in the relationship between these two segments of the

transportation community. We recognize that automakers work in a very competitive environment, and may be challenged to reach consensus on their needs. Similarly, road agencies range in size and capability and don't often speak with a uniform voice. However, if we are to provide infrastructure that supports these new technologies, both physical and digital infrastructure, clearer guidance from the automaker industry would be helpful. There are examples of this collaboration taking place now, such as the V2I Deployment Coalition and AASHTO's Cooperative Automated Transportation (CAT) Coalition, but this collaboration should be greatly expanded to include broader and active participation from the private sector as well as more public sector agencies.

We see three key areas where infrastructure owners should work more closely with ADS developers. First, is standard-setting. AASHTO appreciates that it is not efficient for vehicle manufacturers to have to address a patchwork of state-based policies, laws and regulations that are not consistent or coordinated with each other. In addition, USDOT needs to be actively involved in engaging the public and private sectors in developing national standards for infrastructure and ADS because requirements for infrastructure readiness should be the same across state boundaries so an ADS vehicle can function well anywhere in the country. We ask for consensus from the technology developers and the infrastructure owners to develop these needed standards.

With this being said, it is important to AASHTO that any policy, laws, regulations or guidance do not disrupt the current authority given to states to license the driver of the vehicle or the registration of vehicles. Historically, the regulation concerning the design, construction, and performance of a motor vehicle is a federal obligation that has been under the oversight of the National Highway Traffic Safety Administration (NHTSA) through the Federal Motor Vehicle Safety Standards. The licensing of motor vehicle operators, registration of vehicles, and enforcement of traffic laws has been the domain of states. The development of ADS has the potential to disrupt this separation of design versus operation whereby motor vehicles are no longer driven by a person but by the ADS, and important questions about design, regulation, and certification of complex computer systems must be addressed. The state DOTs believe that these questions, and many others, will be most effectively addressed collaboratively among Federal, state, public and private stakeholders. Already, there are examples of this cooperation happening on a regional basis. For example, the I-95 Corridor Coalition, comprised of 16 states along I-95, has begun to broach this issue by bringing states together to discuss regional strategy and bridge the gap by forming a regional group to establish a regional path forward.

Second, it is important that this engagement be done in partnership with state and local agencies and other private sector partners who own and operate the transportation infrastructure. There are existing structures in place—such as the V2I Deployment Coalition, the Connected Vehicle Pooled Fund Study, and the Collision Avoidance Metrics Partnership—that bring together state and local DOT representatives, research partners, USDOT, auto industry, original equipment manufacturers, and technology vendors. In addition, we would like to see more engagement from non-traditional, original equipment manufacturers.

Finally, in addition to supporting the dialogue with technology developers and asset owners, AASHTO recommends additional federal funding for building new testbeds and maintaining existing ones, with the industry and technology developers testing their hardware and applications on such testbeds. This will enable infrastructure owners and technology developers to better understand each other's requirements. That should lead to better standards and, ultimately, better infrastructure.

A particular and important example of the need for States to understand the operations, so that they can provide better infrastructure, is in the area of data provided via dedicated short range communications (DSRC), which is discussed elsewhere in this statement.

PROVIDE ADDITIONAL FEDERAL RESOURCES FOR RESEARCH

Before closing, let us touch on research needs in this area. Already, there are many research and deployment activities underway in information interface needs and standards, such as SAE J2735 messages, new message standards, equipment deployment and interoperability. At AASHTO, these developments are occurring in a number of places, including the:

- V2I Deployment Coalition,
- Cooperative and Automated Transportation Coalition,
- National Operations Center of Excellence, and
- NCHRP 20-102: Impacts of Connected Vehicles and Automated Vehicles on State and Local Transportation Agencies.

Of particular note concerning existing research activities is the NCHRP 20-102 task order contract administered by the Transportation Research Board. The purposes of this contract are to: identify critical issues associated with connected vehicles and automated vehicles that state and local transportation agencies and AASHTO will face; conduct research to address those issues; and conduct related technology transfer and information exchange activities. This program has been instrumental in moving forward with deployment of connected and automated vehicles. Projects have covered a wide breadth of issues ranging from impacts of regulation and policies on Connected and automated vehicle introduction in transit operations (Task 02) to the implication of automated vehicle on motor vehicle codes (Task 07) to data management strategies (Task 14). Funded under the National Cooperative Highway Research Program supported by the Federal-aid Highway Program, it is imperative that USDOT continues to fund and participate in these critical research projects.

Additionally, the transportation industry has been developing needed data standards and interface requirements. For example, the nature of the data to be shared has been well (but not completely) defined in the SAE J2735 and related standards. Definitions of the Basic Safety Message, the Traveler Information Message, the Signal Phase and Timing Message, and the map geometry messages, among others, include many of the needed elements. Both the automakers and the infrastructure owners and operators are currently working on a Basic Infrastructure Message to define some of the elements of information that can be provided from the infrastructure, such as

information contained on static and dynamic roadway signs, modification in roadway geometry due to construction and maintenance activities, and locations of traffic crashes and incidents. We encourage a continued collaboration through standards bodies like the SAE to define and refine these elements in a way that benefits both the automakers and the infrastructure agencies. Infrastructure owners and operators will similarly make beneficial use of dynamic vehicle response information - indications of localized weather, slippery or uneven roadway surfaces, sudden vehicle movements, etc., and we encourage automakers to provide this kind of information.

Finally, roadway design documents, such as the AASHTO "Green Book" and the Manual on Uniform Traffic Control Devices (MUTCD) will need to be updated to reflect the findings of ADS and connected vehicle research. Collaboration between federal research entities and operator organizations is essential to moving this process forward in a way that doesn't inhibit these technological advancements and the resulting safety benefits.

CONCLUSION

In conclusion, CAVs are in our future and we want the infrastructure to be ready and safer than it has ever been when they are deployed. If deployed properly, this technology will save lives. We hope the information we have presented today will assist the Committee in its efforts to achieve an infrastructure that helps harness the full potential of CAVs, including improving safety, enhancing mobility, and reducing the environmental impact of surface transportation systems.

AASHTO and the state DOTs appreciate the opportunity to present their views to the Committee today.

Senate Committee on Environment and Public Works
Hearing entitled, *"Innovation and America's Infrastructure: Examining the Effects of Emerging Autonomous Technologies on America's Roads and Bridges."*
June 13, 2018
Questions for the Record for Mr. Bill Panos

Chairman Barrasso:

1. Director Panos, as AVs become more prevalent on the roads, one can foresee instances where empty cars venture off to find parking or return home after dropping off passengers at their destinations. Do you predict that AVs will cause changes in traffic patterns? How do you think this will affect the accuracy of traffic planning models?

   Reply. Thank you for the thoughtful question. Traffic planning by states and MPOs is a continuous process. Traffic data is recorded and compiled on a regular basis and HPMS (Highway Performance Monitoring System) data provides traffic counts at least annually. For the present, states believe that they are equipped to detect emerging trends in a timely manner, including any related to connected and automated vehicles (CAVs), and adjust planning, plans, and investment programs accordingly.

   In addition, we note that automated vehicles (AVs) have the potential to provide enhanced data to state and local transportation officials. This could include origin-destination and ridership data. It could also include information on the condition of pavements, signs, and road markings. Should such information become available to state and local transportation officials through AVs, the improved data quality would likely facilitate quality planning. The availability of such information from AVs also could reduce some state data collection costs, freeing up personnel and funds for other important uses.

2. Director Panos, roadways are currently designed with human eyes and decision-making abilities in mind. It is likely that AV sensors and programming will have different needs. How must state DOT maintenance departments adapt in anticipation of AVs to ensure that traffic control devices are visible and understood, especially in work zones and other fluid environments?

   Reply. Thank you for the thoughtful question. We believe that the various developers of AVs are working to ensure that their vehicles perform well in the current environment of highways and streets, including work zones. We are not currently aware of requests by AV developers for changes in the roadway environment or work zone practices beyond the general need to properly maintain pavements, signage and pavement markings, and other aids, such as for work zone identification, which are needed by today's drivers as well. Developers have asked states to adhere closely to the requirements of the MUTCD (Manual on Uniform Traffic Control Devices) – and states do that already, with limited exceptions when they see a need and the exception is permitted by the MUTCD and FHWA. We also believe that developers are working so that AVs can react to elements of the roadway environment in addition to markings and signage. Further, we believe that

these are matters being considered by USDOT in its oversight of AV development and AVs.

Nonetheless, states are dedicated to proper maintenance of signage and markings to the best of their ability within available resources and are also in the early stages of deployment of DSRC (Dedicated Short-Range Communication) equipment in the right-of way of highways. This equipment enables electronic messages between operators of the highway system and CAVs. Messages can include information on traffic conditions, weather, road work zones, and more, enhancing the ability of a vehicle to "see" and understand the roadway environment. As explained in my written testimony of June 13, 2018 the Wyoming Department of Transportation (WYDOT) is currently participating in a USDOT pilot program that, among other things, enables DSRC communication between WYDOT, as the operator of I-80 in Wyoming, and certain CAVs using I-80.

We also note that the Highway Safety Improvement Program (HSIP) specifically provides eligibility for vehicle-to-infrastructure communication equipment. See 23 USC 148(a)(4)(B)(xxv). The HSIP also broadly authorizes other physical infrastructure safety investments, should other types of equipment be needed to address the ability of AVs to understand and respond to the roadway environment. See 23 USC 148(a)(4)(B)(xxviii).

In addition, states will have to be prepared to adjust if it should turn out that AVs need more than what is being provided to today's drivers in terms of pavement condition, markings, signage, information on or delineation of work zones and other roadway environment factors. And states want to be ahead of the game, not chasing technological issues after the fact. That is one of the reasons that my testimony stressed the interest of states in greater collaboration with developers to better understand any infrastructure needs of AVs. We would rather be sure that they are preparing these vehicles to operate in the current roadway environment. In my testimony we identified questions about work zones and impact on AV sensors from potholes and other questions. If enhanced pavement ride quality, or work zone markings, or any other factor or information turns out to be required, we'd like to know, so we can plan and react, including, as applicable, with standards regarding the infrastructure for AV use. So, while to date it seems that the developers are seeking to prepare AVs to operate in the current roadway environment, we'd like more collaboration so we can be more certain whether we have to adjust our infrastructure or information efforts and, if so, how.

Ranking Member Carper:

3. Early, high-profile crashes of autonomous vehicles have sowed public concerns and potentially distrust of autonomous vehicle technology. What improvements to the infrastructure necessary to support autonomous vehicle technology must occur in order to ensure that deployment of AVs builds public confidence? Specifically, what steps can the EPW Committee take to ensure that infrastructure helps to support the safe operation of these vehicles?

   Reply. Thank you for the thoughtful question. As noted in my written testimony of June 13, 2018, it is desirable to ensure eligibility under the federal-aid highway program for any capital investments that may be needed to respond to the emerging deployment of CAVs. At this point we are not aware of specific types of capital investment that would better prepare the roadway environment for AVs that are not eligible. More specifically, we note that the Highway Safety Improvement Program (HSIP) specifically provides eligibility for vehicle-to-infrastructure communication equipment, such as DSRC. See 23 USC 148(a)(4)(B)(xxv). The HSIP also broadly authorizes other physical infrastructure safety investments, should other types of equipment be needed to address developments in this area. See 23 USC 148(a)(4)(B)(xxviii). However, as stated my written testimony, to the extent that any type of highway capital cost related to servicing CAVs comes to the attention of the Committee as not eligible under the current federal-aid highway program, we would support legislation to ensure that eligibility.

   More generally, just as for the current fleet of human driven vehicles, CAVs work better when striping and signage are adequate and in well maintained condition and there is good ride quality on the highways. Pothole filling and most striping are maintenance expenses and are generally outside of the scope of the current federal-aid highway program. Any increase in maintenance would place downward pressure on the ability of state and local governments to make capital investments under the federal-aid highway program. Thus, as to CAVs, as with other issues regarding highway investment, adequate funding for the program is important.

   In addition, more research could help identify possible steps to ensure best use of infrastructure dollars in a world of emerging use of CAVs. AASHTO also supports additional federal investment to maintain and build testbeds, with industry and developers using the testbeds to test their applications.

   Further, it is our understanding that the various developers of AVs are working to ensure that their vehicles perform well in the current environment of highways and streets. We are not currently aware of requests by the developers for changes in the roadway environment beyond the general need to properly maintain pavements, signage and pavement markings, temporary barriers, and other aids, which are needed by today's drivers as well. AV developers have asked states to adhere closely to the requirements of the MUTCD (Manual on Uniform Traffic Control Devices) – and states do that already, with limited exceptions in the rare cases they see a need to deviate and as permitted by the MUTCD and FHWA. We also believe that developers are working so that AVs can

react to elements of the roadway environment other than markings and signage. Further, we believe that these are matters being considered by USDOT in its oversight of AV development and AV vehicles.

States will have to be prepared to adjust, however, if it should turn out that AVs need more than what is being provided to today's drivers in terms of pavement condition, markings, signage, information on or delineation of work zones and other roadway environment factors. And states want to be ahead of the game, not chasing technological issues after the fact. That is one of the reasons that my testimony stressed the interest of states in greater collaboration with developers to better understand any infrastructure needs of AVs. We would rather be sure that they are preparing these vehicles to operate in the current roadway environment. In my testimony we identified questions about work zones and impact on AV sensors from potholes and other questions. If enhanced pavement ride quality, or work zone markings, or any other factor or information turns out to be required, we'd like to know, so we can plan and react, including, as applicable, with standards regarding the infrastructure for AV use. So, while to date it seems that the developers are seeking to prepare AVs to operate in the current roadway environment, we'd like more collaboration so we can be more certain whether we have to adjust our infrastructure or information efforts and, if so, how.

4. Given that the House and Senate AV bills provide NHTSA with new exemption authority to permit thousands of AVs on the roads while also preempting states from regulating AVs, are there minimum infrastructure conditions, design changes, or Vehicle-to-Infrastructure connectivity policies that need to be established at the national level? Should these changes be implemented before widespread deployment occurs?

   Reply. Thank you for the thoughtful question. We defer to NHTSA on the regulation of the vehicle itself. As to the infrastructure, states are already engaged, through test tracks and other programs, in monitoring and working with others in the deployment of AVs. With their commitment to safety, the states are regularly reviewing developments under these tests and pilot programs to determine what next steps are desirable to maintain and enhance safety of the highway infrastructure. In my state, WYDOT is participating in a pilot program under USDOT auspices that involves extensive deployment of DSRC (Dedicated Short-Range Communication) equipment in the right-of way of highways to determine the extent to which it does and can enhance safety in a roadway environment that involves increased deployment of CAVs.

   In short, states are working hard, with a strong safety commitment, to ensure that the technology does not get out ahead of the infrastructure in a way that is not safe. We certainly will speak up if we see obstacles to achieving that goal – and are hopeful that the AV developers and USDOT similarly will work to ensure that need would not arise. As noted in response to the prior question, while we remain highly alert to address any infrastructure needs of CAVs, the context is that the developers, who are subject to USDOT supervision, are working to succeed in the current roadway environment. As also noted in response to the prior question, we'd like more collaboration with developers so

we can be more certain whether we have to adjust our infrastructure or information efforts and, if so, how.

5. In aviation and surface transportation settings, pilots and drivers must be certified to operate vehicles through a licensing process. Given the variation in how AV technologies operate and detect the roadside environment through probabilistic reasoning, should there be a similar licensing approach to certify that AVs are adequately prepared to detect the roadway signs, markings, infrastructural elements, and other users of the road? If yes, how so? If no, how might we otherwise ensure that in complex urban environments, for example, that highly autonomous vehicle technology is prepared to operate safely and effectively?

   Reply. Thank you for the thoughtful question.

   As explained in my written testimony, it is important to AASHTO that any policy, laws, regulations, or guidance not disrupt the current authority given to states to license the driver of the vehicle and register vehicles. Historically, regulation concerning the design, construction, and performance of a motor vehicle is a federal obligation that has been under the oversight of USDOT's National Highway Traffic Safety Administration (NHTSA) through Federal Motor Vehicle Safety Standards. The licensing of motor vehicle operators, registration of vehicles, and enforcement of traffic laws has been the domain of states. The development of AVs has the potential to disrupt this separation of design versus operation whereby motor vehicles are no longer driven by a person but by automated means, and important questions about design, regulation, and certification of complex computer systems must be addressed. The state DOTs believe that these questions, and many others, will be most effectively addressed collaboratively among federal and state officials as well as other public and private stakeholders.

   In addition, and as noted in reply to an earlier question, while state DOTs remain highly alert to address any infrastructure needs relating to the deployment of CAVs, the context is important. That context includes that the AV developers are working to achieve safe operation in the current roadway environment. That current environment includes crowded urban environments and also rural environments, where there may well be less signage and striping, for example. Further, the developers are subject to USDOT supervision, and we believe that USDOT will be concerned with vehicle performance under a range of roadway environments. Nonetheless, and as also noted in response to the prior question, we'd like more collaboration with developers so we can be more certain whether we have to adjust our infrastructure or information efforts and, if so, how.

   In short, state DOTs are strongly committed to maintaining and improving safety as the deployment of AVs advances, such as through proper maintenance of striping and signage and where appropriate, deployment of equipment such as DSRC. We are hopeful that the testing and research under way today, and further research and testing, will yield progress and facilitate the success of further collaboration among states, vehicle and system developers, and USDOT.

6. A significant number of roadway fatalities in this country occur on rural roads. One of the biggest challenges regarding the use of connected and automated vehicles is the lack of required infrastructure features to accommodate them in rural parts of the country. What can and should we be doing to prepare rural America for the expanded use of AVs?

   Reply. Thank you for the thoughtful question. As noted in reply to an earlier question, while state DOTs remain highly alert to address any infrastructure needs relating to the deployment of CAVs, the context is important. The context includes that AV developers are working to succeed in the current roadway environment. That current environment includes rural environments, where there may well be less signage and striping and a need for an AV to rely on data from other roadway characteristics. Further, the developers are subject to USDOT supervision, and we believe that USDOT will be concerned with vehicle performance under rural as well as other roadway environments.

   In short, states are working hard, with a strong safety commitment, to ensure that the technology does not get out ahead of the infrastructure in a way that is not safe, including on rural roads. We certainly will speak up if we see obstacles to achieving that goal – and are hopeful that the AV developers and USDOT similarly will work to ensure that need would not arise.

   However, if needed, states would have to be prepared to act, such as through deployment of DSRC facilities. Also, USDOT, AV developers, perhaps states, and perhaps others may have to work to ensure the ability of AVs to rely on cellular technology. State DOTs and many counties own most of the rural highways. As those highways are often lengthy, they may need solutions other than deployment of DSRC, as installation of DSRC facilities along long, low volume routes could be expensive. However, as there are rural areas of the nation that still do not have adequate cell phone service, we may need to ensure rural connectivity in deployment of CAVs through DSRCs or other approaches in such cases.

7. Truck platooning could be one of the earliest forms of automation technology to be broadly adopted on our nation's roadways. This technology allows trucks to run close to one another in a caravan formation. From an infrastructure perspective, this creates the potential for trucks to use roads more efficiently. On the other hand, bridges have been designed for greater spacing between heavy trucks, therefore more needs to be learned on whether bridge spans can safely handle the added weight. What research has been done into the impact that platooning could have on the structural integrity of our bridges? How many platooned trucks do you think most bridges could reasonably hold? Do you think there should be a limit to the number of vehicles allowed in a platoon in order to avoid this damage to our nation's infrastructure?

   Reply. Thank you for the thoughtful question. Preliminarily, we note that, today, across the country, there are bridges that experience many vehicles on the bridge at the same time, including trucks. Nonetheless, these bridges are functioning safely.

As to platooning, we are aware that FHWA is performing some research on platooning. See, for example the following link to recent FHWA research and testing on platooning. https://www.fhwa.dot.gov/research/truck_platooning/

As our exposure to research on platooning is limited, we respectfully suggest that you may wish to consider contacting USDOT/FHWA for information concerning research on platooning.

8. What should transportation planners begin doing now to accommodate AVs? How long will such planning and implementation require?

Reply. Thank you for the thoughtful question. Traffic planning by states and MPOs is a continuous process. Traffic data is recorded and compiled on a regular basis and HPMS (Highway Performance Monitoring System) data provides traffic counts at least annually. For the present, states believe that they are equipped to detect emerging trends in a timely manner, including any related to connected and automated vehicles (CAVs), and adjust planning, plans, and investment programs accordingly.

Further, it is our understanding that the various developers of AVs are working to ensure that their vehicles perform well in the current environment of highways and streets. We are not currently aware of requests by the developers for changes in the roadway environment beyond the general need to properly maintain pavements, signage and pavement markings, temporary barriers, and other aids, which are needed by today's drivers as well. AV developers have asked states to adhere closely to the requirements of the MUTCD (Manual on Uniform Traffic Control Devices) – and states do that already, with limited exceptions in the rare cases they see a need to deviate and as permitted by the MUTCD and FHWA. We also believe that developers are working so that AVs can react to elements of the roadway environment other than markings and signage. Further, we believe that these are matters being considered by USDOT in its oversight of AV development and AV vehicles.

States will have to be prepared to adjust, however, if it should turn out that AVs need more than what is being provided to today's drivers in terms of pavement condition, markings, signage, information on or delineation of work zones and other roadway environment factors. And states want to be ahead of the game, not chasing technological issues after the fact. That is one of the reasons that my testimony stressed the interest of states in greater collaboration with developers to better understand any infrastructure needs of AVs. We would rather be sure that they are preparing these vehicles to operate in the current roadway environment. In my testimony we identified questions about work zones and impact on AV sensors from potholes and other questions. If enhanced pavement ride quality, or work zone markings, or any other factor or information turns out to be required, we'd like to know, so we can plan and react, including, as applicable, with standards regarding the infrastructure for AV use. So, while to date it seems that the developers are seeking to prepare AVs to operate in the current roadway environment, we'd like more collaboration so we can be more certain whether we have to adjust our infrastructure or information efforts and, if so, how.

9. In Japan, the Japanese government is leading testing of AVs, which is currently restricted to major limited access highways rather than on urban streets. In testimony for this hearing, we also heard from both the Wyoming Department of Transportation and New York City Department of Transportation about their implementation of a USDOT pilot program that explores connected vehicle application concepts within limited, specific pilot sites for a finite duration. This allows the agencies to assess the impacts and evaluate the benefits. What are the pros and cons of taking what could be considered a more limited approach?

   Reply. Thank you for the thoughtful question. At this point in time one could say that all of the various testing and pilot programs in the United States are limited but they are diverse and not limited to freeways. In some cases, they are limited by company, and/or to a state or part of a state, or by number of participating vehicles. We defer to USDOT and individual states as to the extent of permissions for testing and the conditions attached to the testing. In my testimony I described in some detail the testing underway on Interstate 80 in Wyoming.

   If the testing and assessment in the U.S. is more limited than allowed elsewhere in the world, there would be fewer exposures of AVs to the public and reduced risk of any AV accidents. On the other hand, there is a prospect of the US economy being held back through delay of benefits, including potential safety benefits (e.g., if AVs are safer they are displacing less safe human driven trips) and increased mobility for groups in need, such as the disabled and senior citizens.

Senator Whitehouse:

10. As our vehicles move towards automation, this change will require that our infrastructure and roadways are updated to ensure that autonomous vehicles operate safely and efficiently. Upgrades could include well-marked lanes, accurate signage, and traffic lights that can communicate easily and clearly with autonomous vehicles.
    a. What type of upgrades and investment should we be making now to our existing roadways and infrastructure to accommodate autonomous vehicles?
    b. Should we be making changes to our infrastructure and roadways with the intention that the vast majority of vehicles in the future will be autonomous?
    c. If electric vehicles make up the fast majority of autonomous vehicles, what type of infrastructure changes will we need to facilitate this transition?

Reply. Thank you for the thoughtful question. We believe that the various developers of AVs are working to ensure that their vehicles perform well in the current environment of highways and streets, including work zones. We are not currently aware of requests by the developers for changes in the roadway environment beyond the general need to properly maintain signage and pavement markings, temporary barriers, and other aids, which are needed by today's drivers as well. Developers have asked states to adhere closely to the requirements of the MUTCD (Manual on Uniform Traffic Control Devices) – and states do that already, with limited exceptions allowed by the MUTCD. We also believe that developers are working so that AVs can react to elements of the roadway environment other than markings and signage. Further, we believe that these are matters being considered by USDOT in its oversight of AV development and AV vehicles.

States will have to be prepared to adjust, however, if it should turn out that AVs need more than what is being provided to today's drivers in terms of pavement condition, markings, signage, information on or delineation of work zones and other roadway environment factors. And states want to be ahead of the game, not chasing technological issues after the fact. That is one of the reasons that my testimony stressed the interest of states in greater collaboration with developers to better understand any infrastructure needs of AVs. We would rather be sure that they are preparing these vehicles to operate in the current roadway environment. In my testimony we identified questions about work zones and impact on AV sensors from potholes and other questions. If enhanced pavement ride quality, or work zone markings, or any other factor or information turns out to be required, we'd like to know, so we can plan and react, including, as applicable, with standards regarding the infrastructure for AV use. So, while to date it seems that the developers are seeking to prepare AVs to operate in the current roadway environment, we'd like more collaboration so we can be more certain whether we have to adjust our infrastructure or information efforts and, if so, how.

That said, states are mindful of the importance of proper maintenance of signage and markings and are also in the early stages of deployment of DSRC (Dedicated Short-Range Communication) equipment in the right-of way of highways. This equipment enables electronic messages between operators of the highway system and CAVs. Messages can include information on traffic conditions, weather, road work zones, and

more, enhancing the ability of a vehicle to "see" and understand the roadway environment. As explained in my written testimony of June 13, the Wyoming Department of Transportation (WYDOT) is currently participating in a USDOT pilot program that, among other things, enables such communication between WYDOT, as the operator of I-80 in Wyoming, and CAVs using I-80.

We also note that the Highway Safety Improvement Program (HSIP) specifically provides eligibility for vehicle-to-infrastructure communication equipment, which would include DSRC. See 23 USC 148(a)(4)(B)(xxv). The HSIP also broadly authorizes other physical infrastructure safety investments, should other types of equipment be needed to address developments in this area. See 23 USC 148(a)(4)(B)(xxviii).

As to the possibility that many autonomous vehicles would be electric vehicles, a great deal of work is already underway to have EV charging facilities more widely installed where allowed by law. Beyond that, we do not speculate here as to whether such facilities need modification to allow for electric AVs to charge themselves, or whether AVs would be programmed to return (in a timely way) to facilities for human-assisted charging or fueling, as applicable, or whether there would be other approaches or combinations of approaches.

11. Transportation is now the largest source of carbon emissions in the United States, and carbon emissions from cars and light trucks account for almost one-sixth of the nation's total emissions. We should be implementing policies in this sector with an eye towards reducing our emissions.
    a. How can we design the right policies so that autonomous vehicles that enter our roadways are fuel-efficient and help us reduce our transportation emissions?
    b. Do we know how autonomous vehicle adoption will affect overall traffic patterns and the number of miles driven by cars? If not, what is the best way to study and better understand this?

Reply. Thank you for the thoughtful question. To our knowledge, there is ability to automate vehicles that have different levels of fuel efficiency and emissions. Further, regardless of the fuel efficiency of a particular type of AV, there is optimism that AVs will drive more efficiently, helping keep down emissions.

As to overall traffic patterns, traffic planning by states and MPOs is a continuous process. Traffic data is recorded and compiled on a regular basis and HPMS (Highway Performance Monitoring System) data provides traffic counts at least annually. For the present, states believe that they are equipped to detect emerging trends in a timely manner, including any related to connected and automated vehicles (CAVs), and adjust planning, plans, and investment programs accordingly.

Certainly, any significant trends in car mileage, including any such trends resulting from increased use of AVs, would be monitored by states and local governments, who would be able to adjust their investment and operations programs accordingly.

12. Reports suggest that the autonomous vehicle industry could expand into the trucking industry, e-hailing, and ride-sharing industry.
    a. How soon can we expect widespread adoption of autonomous vehicles in these industries?
    b. How can we get ahead of the potential job losses that could occur in traditional trucking and ride-sharing industries if autonomous vehicles are widely adopted?
    c. Do we need to consider job retraining and workforce development policies to ensure that autonomous vehicle deployment does not disrupt the job markets for taxi, bus, and shuttle drivers?

Reply. Thank you for the thoughtful question. How soon AVs will be in substantial use in those or other industries is uncertain, but many expect that AVs will be deployed for commercial uses sooner than in replacement of personal use vehicles. Also uncertain is the extent to which the vehicle fleet becomes AV, and over how long a period of time. So, any impact on any employees who may be tied to current technology could be gradual, or even very gradual if the extent of change is mitigated by increased need for service due to economic growth. Currently, there is a well-documented and growing driver shortage in the trucking industry.

Certainly, the possibility of job training for displaced workers should be considered, but it is hard to know the scale and timing and the need likely would vary by industry.

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Senator BARRASSO. Thanks for your testimony, Mr. Panos. Appreciate it.

Mr. Bhatt.

STATEMENT OF SHAILEN BHATT, PRESIDENT AND CEO, INTELLIGENT TRANSPORTATION SOCIETY OF AMERICA

Mr. BHATT. Chairman Barrasso, Ranking Member Carper, and members of the Committee, thank you for the opportunity to be here today. When last I testified in front of this Committee I served as the Executive Director of the Colorado Department of Transportation. At that time I discussed how a mix of road investment and innovation was needed to solve Colorado's 21st century transportation challenges.

I am now President and CEO of the Intelligent Transportation Society of America, which brings together public sector agencies, private sector companies, and researchers unified by our vision of a better world transformed by intelligent mobility—one that is safer, greener, and smarter. I am honored to be on this panel today with three ITS America members.

Today's hearing takes place at an important time. Just as infrastructure was critical to the development of our economy in the 20th century, maintenance of existing roads, bridges, and other infrastructure, and deployment of intelligent infrastructure will be critical for our global competitiveness in this century.

Advances in robotics, artificial intelligence, and wireless communications have inspired a race to make the next generation of mobility a reality. We are on the leading edge of a technology revolution that will define the way people, goods, and information move in the 21st century. It is a whirlwind of innovation that will change entire industries, as well as transform communities large and small, urban and rural.

That transformation will positively affect both the safety and operation of our transportation system if we do it well. In 2016, 37,461 people died on U.S. roads. That is more than 100 people per day. Pedestrian deaths in that year rose 9 percent. More than 90 percent of roadway crashes are caused in some way by human error. That is a sobering statistic, but we have technologies that will make a difference.

Technologies such as pedestrian automatic emergency braking will use automation to detect pedestrians and prevent tragedies. Through dedicated short range communications and other technologies, we also have the capability to allow vehicles to communicate with other vehicles, smart infrastructure, and other users of the system.

Safety has always been our top priority and is the reason many of us are passionate about this work.

In addition to injuries and fatalities, however, there are major mobility and environmental implications. Americans currently lose roughly 40 hours per person per year sitting in traffic, which costs each driver almost $1,500 per year. Collectively, this drains $305 billion from our economy and wastes 3.1 billion gallons of fuel. Here, technology can play a key role in putting money back into Americans' pockets and improving the environment in which we live. Freight that is stuck in traffic costs Americans more.

This is why, under Colorado's RoadX program in 2016, we sent a truck on the world's first autonomous freight delivery. One of our members, Peloton, is developing driver assisted truck platooning technology that will improve the flow of goods across the country, while reducing fuel consumption of trucks by 7 percent.

Another way of reducing fuel consumption is through electrification, which is an important part of the future of intelligent mobility. Right now, by reducing crashes, we can greatly reduce traffic congestion in this country. More than 50 percent of congestion is caused by non-recurring incidents. Minor fender benders result in hours of frustration and inefficiencies in our system. The deployment of connected vehicle technologies will improve traffic flow across the country.

Connected and automated vehicle technologies and smart infrastructure have the potential to give us back our most precious resource—time. By applying intelligent transportation technologies toward existing infrastructure, we can maximize the efficiency of our system.

Twenty-six States and 45 cities are currently deploying V2I communications that use DSRC. Some of these applications will include bridge and pavement monitoring, curb speed warning, reduce speed areas such as in construction zone, and spot weather warnings, all of which will reduce crashes by providing vehicles and drivers with the most accurate and up to date information.

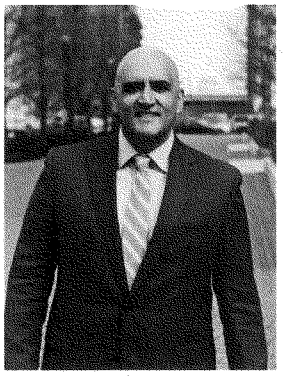
The most important connection between vehicles and infrastructure has historically been the tire. Today there are many ways for vehicles to interface with infrastructure and with other vehicles. We need to prepare for a future that involves a mixed fleet of intelligent and unconnected vehicles. The best way to do this is to maintain our infrastructure in a state of good repair, specifically as that relates to pavement markings and signage.

However, we need to understand signs that work well for human eyes may need to be adapted for machine reading. We also need to understand how cities and States will take these waves of big data that vehicles are producing and turn it into actionable information.

Before I close, I urge Congress and the Administration to identify long-term sustainable funding for the Highway Trust Fund to maintain our infrastructure for all the reasons I have just outlined. In my nearly 10 years as a State DOT leader, I have always said that Departments of Transportation exist to save lives and make people's lives better. I firmly believe that advances in vehicle technology and in smart infrastructure are the best tools in our toolbox to achieve those goals.

Thank you again for this opportunity, and I am happy to answer your questions.

[The prepared statement of Mr. Bhatt follows:]



Shailen P. Bhatt
President & CEO
Intelligent Transportation Society of America
Washington, D.C.

Shailen P. Bhatt is President and CEO of the Intelligent Transportation Society of America (ITS America), where he promotes policies that advance the development and deployment of intelligent transportation technologies throughout the United States.

Previously, Bhatt served as Executive Director for the Colorado Department of Transportation (CDOT), where he led the department in planning for and addressing Colorado's transportation needs. Bhatt oversaw 3,300 employees statewide and an annual budget of approximately $1.4 billion, guiding an organization committed to becoming the best DOT in the country. During his tenure, CDOT launched the Road X program which is focused on deploying innovative technology solutions such as connected vehicles and teaming with the private sector to shape the future of transportation.

Prior to CDOT, he was Cabinet Secretary for the Delaware Department of Transportation, where he managed nearly a billion dollar budget and 2,800 employees. During his tenure, he led the agency response to two hurricanes, introduced performance management to the agency, and reduced agency debt by 30% while delivering $2 billion in infrastructure improvements. He was also responsible for the Delaware Transit Corporation and the DMV. Bhatt also served as an Associate Administrator at the Federal Highway Administration (FHWA).

Bhatt is a respected leader in the transportation field. He previously served on the American Association of State Highway Transportation Officials (AASHTO) Board of Directors and chairs the AASHTO Subcommittee on Transportation Systems Management and Operations (STSMO). He serves as the Chair of the Board of Directors for the National Operations Center of Excellence (NOCoE). In addition, Bhatt is a member of the World Economic Forum's (WEF) Global Agenda Council on the Future of Automotive and Personal Transport. Previously, he served as the Chair of the Executive Committee of the I-95 Corridor Coalition, Diamond State Port Corporation, Board of Directors, and is a former Commissioner for the Northeast Corridor Commission.

Bhatt graduated summa cum laude with a Bachelor of Arts in Economics from Western Kentucky University. He is married with a wife and two daughters.

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Statement of

Shailen P. Bhatt
President and CEO

On behalf of:

The Intelligent Transportation Society of America (ITS America)

BEFORE THE UNITED STATES SENATE COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS

Innovation and America's Infrastructure: Examining the Effects of Emerging Autonomous Technologies on America's Roads and Bridges

June 13, 2018

ITS AMERICA

Testimony

Chairman Barrasso, Ranking Member Carper, and Members of the Committee, thank you for the opportunity to provide the Intelligent Transportation Society of America's (ITS America) perspective on "Innovation and America's Infrastructure: Examining the Effects of Emerging Autonomous Technologies on America's Roads and Bridges."

We applaud the Committee for its interest in infrastructure needs to enable the safe and efficient operation of connected and automated vehicles. I am pleased to be joined on this panel with three ITS America members: New York City Department of Transportation Commissioner Polly Trottenberg; Wyoming Department of Transportation Director William T. "Bill" Panos; and the Center for Advanced Automotive Research at the Virginia Tech Transportation Institute Director Dr. Zachary Doerzaph.

A Better Future Transformed by Intelligent Mobility: Introduction

My name is Shailen P. Bhatt, and I am the President and CEO of ITS America. Before joining ITS America in January, I served as Executive Director for the Colorado Department of Transportation (CDOT). In that role, I oversaw the launch of the RoadX program, which is focused on deploying innovative technology solutions - including connected vehicles - and teaming with the private sector to shape the future of transportation. While at CDOT, I also served as the national Chair of the Vehicle-to-Infrastructure Deployment Coalition and the Chair of the National Operations Center of Excellence. Before CDOT, I served as Cabinet Secretary with the Delaware Department of Transportation and Deputy Executive Director of the Kentucky Transportation Cabinet. I also had the pleasure of serving as Associate Administrator at the Federal Highway Administration under U.S. Department of Transportation Secretary Ray H. LaHood.

It is an honor to testify on behalf of ITS America and our members who have been researching, developing, testing or deploying connected and automated driving technologies for more than two

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decades. Founded as an official advisory board on road technology to the U.S. Department of Transportation, ITS America represents state and city departments of transportation, metropolitan planning organizations, automotive manufacturers, technology companies, engineering firms, automotive suppliers, insurance companies, and research and academic universities. Our Board Chair is Carlos Braceras, Executive Director of the Utah Department of Transportation, and our Vice-Chair is Gary Smyth, Executive Director Global Research and Development Laboratories at General Motors.[1] These members come to one table—ITS America—to shape the next generation of transportation and infrastructure driven by intelligent mobility.

ITS America is united around a shared vision of a better future transformed by intelligent mobility that is safer, greener, and smarter. Our mission is to advance the research and deployment of intelligent transportation technologies to save lives, improve mobility, promote sustainability, and increase efficiency and productivity. For nearly 30 years, ITS America has been educating policy and decision makers at every level of government and in the private sector on policy that supports intelligent transportation technologies. Our focus is policy that accelerates deployment of connected and automated vehicle technology and smart infrastructure; policy that breathes new life into our transportation infrastructure by expanding investments in technologies that support smart and sustainable states and cities; and policy that support new models and modes of transportation including micro-transit, rideshare, carshare, bikeshare, and unmanned systems. That said, our first and foremost priority has been, and continues to be, safety.

[1] The ITS America Board of Directors includes AAA, Arizona Department of Transportation, California Partners for Advanced Transportation Technology at University of California Berkeley, California Department of Transportation, Conduent, Cubic, Delaware Department of Transportation, Econolite, General Motors, GRIDSMART, HELP Inc., Iteris, Kapsch TrafficCom North America, Metropolitan Transportation Commission, Michael Baker International, National Renewable Energy Laboratory, New York City Department of Transportation, Pennsylvania Department of Transportation, Qualcomm, Serco, Southwest Research Institute, State Farm Insurance, Texas A&M Transportation Institute, Toyota, Utah Department of Transportation, and Virginia Tech Transportation Institute.

A Better Future Transformed by Intelligent Mobility: The Next Generation of Mobility

Today's hearing takes place at an important time. Just as infrastructure was critical to the development of our economy in the 20th century, maintenance of existing infrastructure, and deployment of smart infrastructure, will be critical for our global competitiveness in this century. Advances in robotics, artificial intelligence, and wireless communications have inspired a race to make the next generation of mobility a reality. We are entering a technology revolution that will define the way people, goods, services, and information move in the 21st century. It is a whirlwind of innovation that will change entire industries as well as transform communities large and small, urban and rural. It is a new transportation era as dramatic as the period where the car supplanted the horse and buggy.

A Better Future Transformed by Intelligent Mobility: Safer. Greener. Smarter

According to the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA), 37,461 people died in U.S. road crashes in 2016. This is a nine-year high, and it is an increase of 5.6 percent from the 35,485 fatalities in 2015. The 5.6 percent increase, following the 2015 increase of 7.2 percent, is the largest back-to-back percentage increase in fatalities since the 1963-1965 reporting period. In addition, there were 6.29 million crashes in 2015, which resulted in 2.44 million injuries, which is up from 2.34 million in 2014. Another alarming statistic is that pedestrian fatalities rose by nine percent in 2016. Deaths related to reckless behaviors including speeding, alcohol impairment, and not wearing seat belts also continued to increase. Every day on average in the United States, 100 people lose their lives on our roadways.

As fatalities continue to trend upwards, mobility and environmental challenges continue to worsen. According to the 2017 Global Traffic Scorecard by ITS America member INRIX, U.S. drivers spent an average of 41 hours a year in traffic during peak hours, which cost drivers nearly $305 billion, an average of $1,445 per driver. Three of the world's top five most congested cities are in the United

States, with Los Angeles (first), New York (tied for second with Moscow) and San Francisco (fifth) costing upwards of $2.5 billion. According ITS America member Texas Transportation Institute (TTI), congestion produced 56 billion pounds of carbon dioxide (CO2) pollution and contributed to 3.1 billion gallons of wasted fuel in 2015.

We need a safer, greener, smarter future where vehicles don't crash and lives aren't lost on our roads. Today, we are on the cusp of that future transformed by connected and automated vehicle technologies. These technologies have the potential to be the best tools in our toolbox to drastically reduce and potentially eliminate crashes caused by human error. Researchers believe that more than 90 percent of car crashes in the U.S. involves some form of driver error, so driverless and driver assisted systems are strongly believed to have the potential to reduce damage and fatalities on our roads. Furthermore, fewer crashes mean less congestion, so it will be a future with reduced travel delays, more travel time reliability, reduced fuel consumption, and more sustainable and resilient communities.

Connected and automated vehicle technologies also have the potential to expand access to transportation. Older Americans and people with disabilities are demographics that are impossible to ignore. According to the U.S. census, residents age 65 and over grew from 35.0 million in 2000, to 49.2 million in 2016, accounting for 12.4 percent and 15.2 percent of the total population, respectively; and nearly one in five people have a disability. They also represent a significant demand for transportation services, with explosive growth in travel occurring should fully automated vehicles succeed in expanding mobility access. We hope to have a future in which people with disabilities have full freedom of transportation; older adults have greater independence; and people in underserved communities and transit deserts - who are often low-income, minority, and immigrant - will have better work opportunities, better education, and access to better healthcare.

Connected vehicles have arrived, and automated vehicles are coming, but this should come as no surprise because we have seen technology being added to cars, trucks, and buses since the 1950s. Cruise

control, an early example of vehicle automation, was first introduced in the 1958 models of the Chrysler Imperial, New Yorker and Windsor. According to NHTSA, vehicle safety technologies have been researched, developed, tested, and deployed safely over nearly 70 years, include cruise control, anti-lock brakes, electronic stability control, blind spot detection, forward collision warning, lane departure warning, rearview video systems, vehicle and pedestrian automatic emergency braking, pedestrian protection, rear cross traffic alert, and lane centered assist.

New vehicle technologies, in particular cooperative crash avoidance and automated driving systems, are game changers. We now have the technical capability to connect vehicles to other vehicles, to the infrastructure, and to pedestrians - collectively referred to as Vehicle-to-Everything (V2X) communications or Connected Vehicle - via the Dedicated Short Range Communications (DSRC) standard utilizing the 5.9 GHz spectrum band. In particular, advanced traffic management infrastructure, Vehicle-to-Infrastructure (V2I) communications, and Vehicle-to-Pedestrian (V2P) communications can reduce crashes, smooth traffic flow, reduce pollution, and most importantly, save lives. As advanced vehicles add automation features, from adaptive cruise control, to freeway "autopilot," all the way to a completely driverless mode, having infrastructure accommodate these advanced vehicles will be a challenge, but the success of the technology will dramatically affect how we live and how we travel.

A Better Future Transformed by Intelligent Mobility: Vehicle-to-Infrastructure

The modern world literally turns on the boundary of where the tire rubber meets the paved road. For over a century, this was the most important interface between the car and the infrastructure. For automakers, the objective was always to design vehicles that were "road friendly" to the greatest extent practical. However, with new information and wireless technologies, there is a new interface -- a digital interface between the car, driver, and the road infrastructure. This has presented an opportunity for road infrastructure operators to manage traffic and improve safety in ways that were previously unknown.

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The concept of V2I was to provide the vehicle and the driver information about infrastructure operations -- weather and pavement condition, how signals were directing traffic, and even the location of potential hazards at intersections and other critical road safety hotspots. V2I communications benefit from interoperability with vehicle equipment. Major domestic and global automakers have agreed to standards that allow not only vehicles to communicate with one another to improve safety, but allow infrastructure operators to use that same capability to improve the safety and productivity of their operations. As NHTSA considers establishing V2X as a Federal Motor Vehicle Safety Standard (draft FMVSS 150), some companies have moved ahead of the agency. ITS America members Toyota and Volkswagen have already committed to deploying DSRC V2X in Japan and Europe respectively. Toyota and ITS America member General Motors have committed to deploy DSRC V2X in new cars over the next decade in the United States.

NHTSA estimates that safety applications enabled by V2V and V2I could eliminate or mitigate the severity of up to 80 percent of non-impaired crashes, including crashes at intersections or while changing lanes. Twenty-six states and 45 cities are deploying V2I communications that use the DSRC safety spectrum band to enhance safety, reduce crashes, and decrease fatalities. V2I deployments include expansions of the Safety Pilot Model Deployment in Ann Arbor (MI), large Pilot Deployments in New York City (NY), Tampa (FL), and Wyoming, and the Smart City Challenge in Columbus (OH).

DSRC supports multiple V2I applications to include, for example, red light violation warnings, reduced speed zone warnings, curve speed warnings, and spot weather impact warnings. V2I in the near future may also support other applications that will disseminate the condition of the infrastructure such as bridge integrity, and may even collect data from cars that describe the condition of pavement. ITS America, along with the American Association of State Highway Transportation Officials (AASHTO) and the Institute of Transportation Engineers (ITE) instituted the Signal Phase and Timing (SPaT) Deployment Challenge. SPaT would enable an automated vehicle to be advised of the future settings of any oncoming traffic signal that it might encounter, as well as (or instead of) the traffic signal only using

its location to determine the appropriate timing. This technique has been shown to manage queues and reduce delays significantly.

The SPaT challenge seeks "20 by 2020" -- the goal of each of all 50 states to deploy V2I with SPaT broadcasts in at least one corridor or network (approximately 20 signalized intersections) by January 2020. Infrastructure must be deployed in coordination with vehicle equipage of DSRC. According to Navigant Research in a 2017 study, annual sales of light duty vehicles with factory-installed V2X are expected to reach nearly 70 million by 2025, with revenue from sales of original equipment and aftermarket DSRC-based V2X systems projected to reach more than $25.5 billion in the same period.

As the auto industry's readiness to commit to deploying V2X has grown with more mature standards and an ever expanding supplier base for equipment, so too has market competition. Recent wireless technology alternatives to DSRC V2X include Cellular Vehicle to Everything (C-V2X) technologies which is undergoing further standardization, field validations and assessment. Designed to work on an 4G LTE-based telematics unit and intended to be compatible with future 5G, the C-V2X direct communication mode also offers V2V, V2I, and V2P (without the involvement of a cellular network, or cellular network subscription) by operating on designated and harmonized 5.9 GHz ITS spectrum. Global C-V2X field validations with car manufacturers, automotive ecosystem participants, and in cooperation with regional governments are currently underway in Germany, France, Korea, China, Japan and the United States, with industry deployment expected to take place as early as 2020. ITS America members Qualcomm Technologies, Panasonic, and the Colorado Department of Transportation are assessing C-V2X capabilities on select roadways this year. At nearly the same time, Institute of Electrical and Electronics Engineers (IEEE) 802.11 Working Group has formed a Study Group to consider a Next Generation V2X (NGV) project that is addressing potential changes to the current DSRC V2X wireless standard that had been already tested assessed and validated extensively in major V2X operational tests in Ann Arbor Michigan (University of Michigan Safety Pilot Model Deployment 2012-2015) and several other locations over the last several years.

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No matter the path the underlying wireless technology may take, V2X applications have incredible potential to dramatically improve the safety and operational performance of our road infrastructure. According to NHTSA, V2I technology helps drivers safely negotiate intersections and could help prevent 41 to 55 percent of intersection crashes. Another connected vehicle safety application that helps drivers with left turns at intersections could help prevent 36 to 62 percent of left-turn crashes, according to NHTSA. In addition to the lives saved, just these two applications alone could prevent up to 592,000 crashes and 270,000 injuries each year.

Vehicle automation is also likely to be supported by V2X systems in the near future. One of our members, Peloton Systems, is connecting freight trucks using direct V2V communications that allows a rear truck to to react immediately to the actions of the front truck traveling at highway speeds. By electronically coupling the trucks in this way, they accelerate and brake together and can safely operate at closer distances to form a platoon. This kind of connected "cooperative" automation improves safety as well as fuel efficiency and emissions -- Peloton has realized savings of more than seven percent when V2V platooning using industry standard tests.

As we prepare for deployment of connected and automated vehicles by addressing infrastructure needs, it may be instructive to take a look back at the Fixing America's Surface Transportation Act (FAST Act). ITS America commends the Committee's leadership, which made V2I an eligible activity under most of the core highway programs including the National Highway Performance Program, Surface Transportation Block Grant Program, Congestion Mitigation and Air Quality Program, Highway Safety Improvement Program, and Advanced Transportation and Congestion Management Technologies Deployment Program. Your action enables many states and cities to invest in V2I to avoid or mitigate vehicle crashes and provide mobility and environmental benefits.

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A Better Future Transformed by Technology: Road Environment and Traffic Management[2]

As ITS America generally believes that to maximize the safety benefits of connected and automated vehicles, roadways must be better maintained and modernized, traffic signals and ramp meters must be further standardized and connected, and road signage and lane markings may need to be maintained or upgraded.

While designs vary, most automated vehicles analyze real-time inputs from a combination of active sensors (e.g. emitting systems such radar, LIDAR, infrared, piezoelectric sensors etc.), passive sensors (e.g. non-emitting camera based detection/classification) and even vehicle-infrastructure communications (e.g. traffic signals and vehicles that beacon safety and other status information). An automated vehicle then processes those inputs, compares results with preloaded maps and driving models, plots a path, and sends instructions to the vehicle's powertrain and control systems to manage acceleration, braking, and steering. Ideally, supervised and/or unsupervised "machine learning" occurs to improve performance of these processes over time – extending and expanding safety capabilities across vehicle makes and models.

Roadway environments, however, are diverse -- from freeway, arterial, collector/distributor, and local roads, intersections, traffic circles and ramps, each with different lane configurations and access rules, and traffic control device placement that support these configurations. These configurations also change temporarily with specialized so-called "managed" lanes such as reversible lanes, or planned or ad-hoc road construction within work zones, with some construction efforts leading to redesign of the roadway. Weather conditions also are a key environmental factor, especially where weather and infrastructure

[2] ITS America acknowledges the contributions of members Texas Department of Transportation, Utah Department of Transportation, and WSP in analyzing road environment and traffic management requirements for automated vehicles. We also want to thank the Alliance of Automobile Manufacturers and the American Trucking Associations for their contributions.

configuration interact (e.g. where precipitation may degrade visibility or utility of traffic control devices etc.).

Consistency in the implementation and maintenance of traffic control devices is therefore important, and in some select circumstances might be more important than diversity and innovation in design. Signage and markings provides direction, guidance and warnings to drivers. Some states elect to follow the Federal Manual of Uniform Traffic Control Devices (MUTCD), while other states may generate different iterations of the Manual. Even if a road sign design is not the easiest to perceive or assimilate for a human driver, for an automated vehicle vision detection and classification system -- it is likely easier to learn how to interpret a single but ambiguous traffic sign as opposed to having to learn to interpret a large number of different but more easily identifiable signs. Not only is consistency important, maintenance is also vital. In some circumstances, poorly maintained markings and signage can be worse than having no markings and signage at all, since they may cause unintended responses by the automated driving system.

Road surface conditions are also important. Poorly maintained roadway surfaces (buckled asphalt, potholes, etc.) could increase the risk of damaging vehicle sensors. Damage to sensors can compromise vehicle performance and may force a vehicle into a degraded state where automation must be deactivated. Poor surface conditions will decrease the vehicle's lifetime durability and increase the cost and complexity of vehicle operations and maintenance.

There are new infrastructure technologies, however, that may improve automated vehicle performance. There is an effort to design new types of road markings, signs, and other kinds of connected infrastructure that would make driving in highly automated vehicles potentially safer. Existing traffic control devices, specifically signage, road markings and traffic signals were designed for human drivers and use shapes colors, graphs and texts to convey relevant information. Making these devices easier for machines to read, or to embed additional static data that would be relevant to automated driving system

is a potential innovation. For example, some companies have experimented with embedding machine-readable GPS coordinates and other encoded metadata into road signs that are invisible to drivers but provide useful information to driverless cars. In its Interstate 75 Modernization project, the Michigan Department of Transportation deployed advanced all-weather lane markings, retroreflective signs with smart sign technology and DSRC devices for vehicle-to-infrastructure communications. These innovations improve the robustness of automated vehicle sensing and perception.

Automated vehicles may even improve infrastructure by reporting deficiencies. Automated vehicle operators and infrastructure stakeholders may in the future be able to create a common mechanism for automated vehicles to report an infrastructure item which needs a repair. The Utah Department of Transportation (UDOT) Roadway Imaging and Inventory program called for the collection of 14,000 miles of geolocated road geometry, pavement distress, surfaces, imagery, lane-mile, bridge clearance and sign data and was expanded to require collection of nearly all right-of-way assets. Utah has also made inventory data available across all divisions within the department through its UPLAN website, which includes data describing the roadway asset purpose and function, as well as other metadata.

Such infrastructure asset management strategies may support automated vehicle deployment in a supplemental way. Planned construction and temporary or permanent changes to roadways, e.g. intersection geometry, traffic pattern changes (i.e. rush hour and other time-dependent right of way operations) can be tracked and information disseminated. Such modifications include events such as changes to traffic light positions, the introduction of new traffic light types, and changes to road geometry or lane lines such as when new pavement islands are created or double yellow lines are moved that modify traffic flow. Databases also can contain information and location about the signs and signals which do not conform to national standards, as well maps of where local traffic codes may change from jurisdiction-to-jurisdiction.

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Such "digital infrastructure" is important. Additionally, sharing information regarding weather and traffic flow conditions will increase roadway safety and streamlined mobility.
Automated vehicles may find it difficult to navigate construction zones, accident areas, and other unexpected scenarios. Since some current automated vehicle prototypes rely on pre-compiled maps of the roadway for perception and path planning, temporary changes to the roadway may need to be disseminated on short notice.

This digital infrastructure requires connectivity to disseminate information about adverse conditions and events. Events may include crashes and other traffic incidents, construction, weather and other sources of congestion. In the future, this may require a means for local traffic operating management centers to directly message driverless vehicles. For traffic events that require split second responses, it may also require other vehicles or personnel at the scene of a work zone or a crash to send secure ad-hoc safety or traveler information messages either vehicle-to-vehicle, to or from the roadside or pedestrians at the scene. It should be noted, however, that the FCC seeks to allow unlicensed services supporting wireless consumer internet access in its current proceeding on the 5.9GHz spectrum band, and final action in the proceeding may preclude some types of DSRC/V2X applications that have been described so far. Although supportive of sharing DSRC spectrum with Wi-Fi in principle, ITS America members are concerned that any regulatory action that reduces the effectiveness of DSRC could mean more unnecessary crashes, injuries and potentially deaths on our nation's roads.

More automated vehicle research is still needed to address infrastructure needs. New driving conventions, such as how robotic vehicles might "wave through" pedestrians on crosswalks, or they how to identify and pull over for emergency vehicles, will be required for robotic vehicles to interact with other road users. Operations research must be conducted in order to ensure that the infrastructure operations and traffic codes can be adjusted where necessary to improve traffic safety while accommodating these new classes of advanced vehicles. Understanding how to transition from driver and driverless needs to be studied. Human-controlled vehicles are likely to remain on the roads for many

years and even decades to come. How people and driverless cars will mix together is a question that needs to be addressed. Many of our academic and research members have been active in advising state and local transportation authorities on how to plan for vehicle and infrastructure connectivity and automation

While I was at Colorado DOT, we understood in particular the need to address infrastructure needs to improve safety and accommodate new connected and automated vehicle technologies. We worked to improve the reflectivity and durability of roadway pavement markings throughout major corridors in the state. We also deployed V2I DSRC along Interstate 70. And of course, we worked with tech companies to begin to explore the capabilities of automated vehicles. In 2016, we worked with Otto and Uber to allow their 120-mile demonstration of the world's first commercial delivery by a self-driving truck.

A Better Future Transformed by Intelligent Mobility: Electric Vehicle Charging Infrastructure

An increasing number of automakers are committing to deploy automated electric vehicles. ITS America believes that an automated electric vehicle represents one of the best ways to reduce carbon dioxide (CO_2) pollution and our nation's dependence on oil from volatile and unpredictable regions of the world.

One of my last acts as head of the CDOT was to work across state agencies to help implement Governor John Hickenlooper's Executive Order D 2017-015, "Supporting Colorado's Clean Energy Transition." The executive order directs state agencies to develop a plan to electrify Colorado's transportation corridor.

Despite the recent growth in Colorado's electric vehicle (EV) market, including that the first eight months of 2017 saw EV sales jump 73 percent over the same period in 2016, we found significant barriers to adoption. These barriers included a lack of public charging stations, particularly EV fast-charging along major transportation corridors. Consumers were apprehensive about the availability of

public charging, including local, community-based charging stations and fast-charging stations along Colorado's transportation corridors, and build-out of an EV fast-charging network would likely require significant public funding due to the high cost of installation. These barriers are not unique to Colorado. Now, as head of a national association, I hear similar concerns from our member states and cities as well as automobile manufacturers. As companies prepare to deploy automated electric vehicles, ITS America calls on federal, state, and local governments and the private sector to build-out the charging infrastructure to support the next generation of mobility powered by electricity.

A Better Future Transformed by Intelligent Mobility: An Infrastructure Plan that Lays the Groundwork for Connected and Automated Vehicles

Once the envy of the world, our increasingly outmoded roads, bridges, transit, freight, and intercity passenger systems are struggling to move the nation's technology-driven economy. Investment in far-sighted intelligent transportation technologies will enable scarce infrastructure funds to reach farther and with longer-lasting results. As owners, operators, builders, innovators, and users of transportation infrastructure, we urge Congress to pass, and the Administration to support, an infrastructure bill that prioritizes investments in intelligent transportation technologies that modernize the infrastructure that will enable the safe and efficient operation of connected and automated vehicles.

ITS America recommends that an infrastructure bill should:

• *Leverage existing FAST Act programs*: Increase funding for FAST Act programs. Intelligent transportation technologies, including V2I, are eligible uses of most FAST Act highway program funds. Specifically increase funding for the Intelligent Transportation Systems Program, Advanced Transportation and Congestion Management Technologies Deployment Program, Technology and Innovation Deployment Program, and for the Surface Transportation Block Grant program, and

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Congestion Mitigation and Air Quality program – flexible programs that often fund intelligent transportation deployment activities.

• *Create grants for emerging technologies that support congestion relief:* Provide new funding for intelligent transportation deployment activities that support congestion relief. The program would include both formula and grant funding. Eligible projects would include capital and operational investments that improve system safety and performance. Examples include priced managed lanes; transportation demand management programs; strategic transit investments; advanced parking, freight delivery, and incident management systems; and programs to support the deployment of connected and automated vehicles, including V2V and V2I technologies.

• *Expand opportunities for smart communities:* Build on the successes of the 2015 Strengthening Mobility and Revolutionizing Transportation (SMART) Cities Challenge administered by the U.S. Department of Transportation by including new federal grants to expand opportunities for communities – large and small/urban and rural – to compete for resources that will fund innovative and sustainable smart transportation projects. Projects should emphasize maturing technologies and performance goals. Incentivize the connection of smart cities and assist in the advancement of testing and deployment of automated vehicles

• *Increase development of Electric Vehicle (EV) charging infrastructure:* Additional development of EV charging station corridors based on federal and state incentive projects as well as public private partnerships. Continue to look at new technologies such as inductive charging to speed the deployment of EVs.

• *Develop additional opportunities for broadband deployment:* Provide new federal funding and grants for broadband in unserved areas—both rural and metropolitan—to support the deployment of intelligent transportation applications that depend on connectivity.

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• *Provide investments to stabilize the Highway Trust Fund and more resources for intelligent transportation technologies:* Provide new and long-term investments to stabilize the Highway Trust Fund, increase federal funding for intelligent transportation technologies, and provide a multi-faceted approach to leveraging public and private resources.

A Better Future Transformed by Intelligent Mobility: A National Framework for Automated Vehicle Development and Deployment

Connected and automated vehicle technology is the best tool in our toolbox to drastically reduce crashes. As we have seen over the past few months, technology is not infallible. While we must study each of these fatalities, we must not forget that every day on average in the United States, 100 people lose their lives on our roadways.

Our members must redouble efforts to ensure any deployments of automated vehicles are safe. Private sector innovators — car and tech companies alike — along with research organizations, must work with government agencies to safeguard the public. We need a federal framework for automated vehicle development and deployment, as well as reinforced state and local roles. We must allow these vehicles to drive the hundreds of millions of miles required to make them safer. Automated vehicles are much like new drivers — they have a great capacity to learn, but they need experience. Just as a human driver improves with time, so too will automated vehicles. Unlike humans, however, they do not get distracted, they won't fall asleep, and they will not drive under the influence.

ITS America believes that the AV START Act (S. 1885) achieves these objectives by maintaining state and local authority over the operation of highly automated vehicles on public roads and memorializing the federal role in ensuring the safety of highly automated vehicles as it relates to design, construction, or performance. The bill's Report language is clear that "performance with regards to NHTSA's traditional authority over design, construction, or performance, excludes the act of a highly automated

vehicle or a vehicle equipped with automated driving systems from complying with state and local traffic laws and rules." We also believe that the recent crash in Tempe (AZ) involving a highly automated vehicle highlights the need for federal oversight of how manufacturers are addressing the safety of these vehicles. Currently, there are no federal regulations specifically governing the safety of highly automated vehicles. The AV START Act would put in place federal oversight of the safety of highly automated vehicles. The AV START Act's Safety Evaluation Report would require manufacturers and other entities developing and testing highly automated vehicles to explain to NHTSA and the public how vehicle safety is being addressed, including how they would address pedestrian protection.

We think it is important to point out that the AV START Act creates a process where developers can apply to NHTSA to demonstrates that features of their products provide equivalent level of safety to those required by Federal Motor Vehicle Safety Stands (FMVSS). One of the most important aspects of the bill is that it requires NHTSA to develop FMVSS for self-driving vehicles on an expedited basis. This is necessary because the automobile and technology industries need experience operating these vehicles in sufficiently substantial numbers to generate the broad data across a multitude of scenarios and environmental operating conditions necessary to ensure safety. As these supervised automated vehicles gain experience, they will develop greater awareness of roadway hazards, which is key to preventing crashes.

We can have a better, safer future transformed by connected and automated vehicles. We can have a world in which cars don't crash. We must learn from the recent tragedies, but we cannot lose sight of our goal to prevent future tragedies and save more lives.

A Better Future Transformed by Intelligent Mobility: Conclusion

I would be remiss if I did not strongly urge Congress and the Administration to identify long-term and sustainable funding for the Highway Trust Fund before the FAST Act expires in 2020 to ensure the law

is reauthorized on time. Maintaining our infrastructure is vital. Funding for research examining the transition to a connected and automated vehicle environment and a "connected infrastructure" is also important. This kind of research requires funding.

In conclusion, the future of mobility is happening today with ITS America members. From connected and automated vehicles and infrastructure to delivery drones to the Internet-of-Things to Mobility on Demand to When-I-Want-It/Where-I-Want-It-Logistics, our members are researching, developing, testing, and deploying technology that will create a better future. In fact, last week I was with more than 2,500 people - from corporate executives to city, state and federal government officials - at our annual meeting in Detroit. We spent hours discussing automated vehicles on panels such as "Connected and Highly Automated Vehicles are Coming: What Needs to be Done Now to Prepare for Them" with Detroit, Colorado Department of Transportation, New York City Department of Transportation, Utah Department of Transportation, Texas Department of Transportation, and AECOM. In addition, the Federal Highway Administration launched its National Dialogue on Highway Automation at our annual meeting.

Changes are happening today that will fundamentally affect how people interact with transportation in the months and years ahead. ITS America is helping states, cities, the private sector, and researchers as we work toward our vision of a better world transformed by intelligent mobility - one that is safer, greener, and smarter.

Thank you again for the opportunity to testify today, and I am happy to answer any questions you may have.

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ITS America advances the research and deployment of intelligent transportation technologies to save lives, improve mobility, promote sustainability, and increase efficiency and productivity. For more information, visit https://www.itsa.org/.

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Senate Committee on Environment and Public Works
Hearing entitled, *"Innovation and America's Infrastructure: Examining the Effects of Emerging Autonomous Technologies on America's Roads and Bridges."*
June 13, 2018
Questions for the Record for Mr. Shailen Bhatt

Chairman Barrasso:

1. Mr. Bhatt, the success of AV implementation is going to rely on a meaningful collaboration between government agencies and the private sector. What actions are industry leaders taking to anticipate and address the infrastructure needs required to accommodate AVs?

RESPONSE: Automakers and technology companies are designing and building automated vehicles to operate on existing infrastructure. These companies understand that America's infrastructure is aging and increasingly outmoded. They are also aware of the funding challenges to improving our nation's infrastructure. As a result, automakers and technology companies are designing and building automated vehicles that will integrate with human drivers and navigate diverse infrastructure conditions. For example, Intelligent Transportation Society of America ("ITS America") Board Member General Motors is designing and building self-driving cars to safely operate among aggressive drivers, jaywalkers, bicyclists, delivery trucks, construction, unprotected left turns, 4-way stop signs and countless other factors that arise.

To optimize the performance of automated vehicles, road signage and lane markings should be maintained in a state of good repair and traffic signals and ramp meters standardized and connected. Well defined lane markings will not only help automated vehicles, they will also help human drivers more easily read them. Consistency for traffic control devices like road signs and traffic signals would also be helpful, with guidance from the Manual of Uniform Traffic Control Devices. Preparing for Vehicle-to-Everything (V2X) will provide an additional layer of information to the automated vehicle, to the pedestrian, and to the infrastructure. Advanced traffic management infrastructure, Vehicle-to-Infrastructure (V2I) communications, and Vehicle-to-Pedestrian (V2P) communications can reduce crashes, smooth traffic flow, reduce pollution, and most importantly, save lives. V2X communications in particular can support crash avoidance and driver assistance for road user categories that were particularly vulnerable to crashes, such as motorcycles, bicycles, and emerging unconventional systems such as electric scooters or robotic delivery drones that may share the road with conventional cars, trucks, and buses. Vulnerable road users such as cyclists can use V2X communications to actively signal their presence to conventional vehicles to avoid conflicts that can lead to crashes.

Society of Engineers (SAE) Level 1 systems (SAE J3016, Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems) like Driver-Assistive Truck Platooning also are designed to operate on today's existing multi-lane, divided, limited-access

highways and require no new infrastructure or infrastructure changes. These systems improve the safety and efficiency of freight transportation by enhancing the teamwork between drivers while

they navigate the roadway, allow traffic to enter and exit the highway, react to potential cut-ins, and coordinate lane changes. Pairs of platooning trucks will be able to navigate the roadway and interact with other traffic just as other trucks do today.

Safe deployment of automated vehicles will require a meaningful collaboration between government and the private sector. At ITS America, automakers and technology companies are collaborating with states and cities to plan for automated vehicles. Our members are at one table discussing legislation (Automated Vehicle Task Force led by Texas Department of Transportation and EasyMile), potential automated vehicle policies for the reauthorization of the FAST Act (Smart Infrastructure Task Force led by Regional Transportation Commission of Southern Nevada and HNTB), connected automated vehicle technologies (Vehicle-to-Everything Task Force led by Colorado Department of Transportation and Toyota), and cybersecurity (Cybersecurity Task Force led by AECOM and Metropolitan Transportation Commission San Francisco Bay Area).

Our members are demonstrating leadership and collaboration to ensure the safe testing and eventual deployment of automated vehicles. An example of this is ITS America former Board Chair and Michigan Department of Transportation Director Kirk Steudle. Under his leadership, the Michigan Council on Future Mobility was established. This council, established in state law, has a membership nearly equally divided between public and private sector membership with two chairs--one public and one private. Its charge is to provide policy recommendations to the state legislature and Governor on the development of technology involving autonomous, highly automated and connected vehicles. Other examples of public/private efforts are the automated vehicle testing facilities at the University of Michigan's "Mcity" and the American Center for Mobility in Michigan.

Collaboration on automated and connected vehicle technologies and infrastructure starts with ITS America's leadership. Our Board Chair is Carlos Braceras, Executive Director of the Utah Department of Transportation, and our Vice-Chair is Gary Smyth, Executive Director Global Research and Development Laboratories at General Motors. The ITS America Board of Directors includes AAA, Arizona Department of Transportation, California Partners for Advanced Transportation Technology at University of California Berkeley, California Department of Transportation, Conduent, Cubic, Delaware Department of Transportation, Econolite, General Motors, GRIDSMART, HELP Inc., Iteris, Kapsch TrafficCom North America, Metropolitan Transportation Commission, Michael Baker International, National Renewable Energy Laboratory, New York City Department of Transportation, Pennsylvania Department of Transportation, Qualcomm, Serco, Southwest Research Institute, State Farm Insurance, Texas A&M Transportation Institute, Toyota, Utah Department of Transportation, and Virginia Tech Transportation Institute.

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Ranking Member Carper:

2. *Early, high-profile crashes of autonomous vehicles have sowed public concerns and potentially distrust of autonomous vehicle technology. What improvements to the infrastructure necessary to support autonomous vehicle technology must occur in order to ensure that deployment of AVs builds public confidence? Specifically, what steps can the EPW Committee take to ensure that infrastructure helps to support the safe operation of these vehicles?*

RESPONSE: Connected automated vehicle technologies are the best set of tools in our traffic safety toolbox to drastically reduce crashes. As we have seen over the past few months, technology is not infallible. While we must study each of these fatalities, we must not forget that every day on average in the United States, 100 people lose their lives on our roadways. Our members must redouble efforts to ensure any deployments of automated vehicles are safe. Private sector innovators — car and tech companies alike — along with research organizations, must work with government agencies to safeguard the public.

We need a federal framework for automated vehicle development and deployment, as well as reinforced state and local roles. We must allow these vehicles to drive the hundreds of millions of miles required to make them safer. Automated vehicles are much like new drivers — they have a great capacity to learn, but they need experience. Just as a human driver improves with time, so too will automated vehicles. Unlike humans, however, they do not get distracted, they won't fall asleep, and they will not drive under the influence.

An important but overlooked part of awareness and confidence is that features of automated driving are advancing in the marketplace. Cruise control, an early example of vehicle automation, was first introduced in the 1958 models of the Chrysler Imperial, New Yorker and Windsor. Whether it is adaptive cruise control, parking assistance, lane integrity or rear object detection, current production vehicles are available with features that use safety technology to aid the driver.

As we prepare for automated vehicles, it may be instructive to look back at the FAST Act. Potential infrastructure capital costs associated with automated vehicle deployment, such as V2I, are already an eligible activity under the FAST Act. Recognizing that there could be infrastructure improvements that are not currently eligible, the ITS America Smart Infrastructure Task Force has been charged to complete a review and report back to ITS America leadership in 2019. If there are automated vehicle infrastructure improvements currently not eligible, ITS America will urge the Committee on Environment and Public Works to make these improvements eligible in the reauthorization of the law.

I previously referenced how poorly maintained roadway, bridge, and tunnel surfaces (buckled asphalt, potholes, etc.) can increase the risk of damaging vehicle sensors. Damage to sensors can compromise vehicle performance and may force a vehicle into a degraded state where automation must be deactivated. Poor surface conditions will decrease the vehicle's lifetime durability and increase the cost and complexity of operations and maintenance. Therefore, ITS America urges the Committee on Environment and Public Works to continue the FAST Act's priority of bringing transportation infrastructure to a state of good repair in the reauthorization of

the law. I also want to reiterate that automakers and technology companies are designing and building automated vehicles to operate with existing infrastructure.

In terms of other specific policy actions for the Committee on Environment and Public Works, ITS America urges the Committee to maintain eligibility and funding for V2I communications equipment in the reauthorization of the FAST Act. We also urge the Committee to look at ways to incentivize states to use FAST Act funding to increase the deployment of V2I communications equipment. Due in large part to funding under the FAST Act, 29 states and 45 cities are deploying V2I communications that use the DSRC safety spectrum band to enhance safety, reduce crashes, and decrease fatalities. V2I deployments include expansions of the Safety Pilot Model Deployment in Ann Arbor (MI), large Pilot Deployments in New York City (NY), Tampa (FL), and Wyoming, and the Smart City Challenge in Columbus (OH). NHTSA estimates that safety applications enabled by V2V and V2I could eliminate or mitigate the severity of up to 80 percent of non-impaired crashes, including crashes that occur at intersections or while changing lanes.

It should be noted, however, that the Federal Communications Commission (FCC) seeks to allow unlicensed services supporting wireless consumer internet access in its current proceeding on the 5.9 GHz spectrum band, and final action in the proceeding may preclude some types of DSRC/V2X applications that have been described so far. Although supportive of sharing DSRC spectrum with Wi-Fi in principle, ITS America members are concerned that any regulatory action that reduces the effectiveness of DSRC could mean more unnecessary crashes, injuries and potentially deaths on our nation's roads. We urge the Committee on Environment and Public Works to communicate to the FCC and U.S. Department of Transportation (USDOT) the importance of preserving the 5.9 GHz spectrum band for transportation critical safety communications.

3. *Given that the House and Senate AV bills provide NHTSA with new exemption authority to permit thousands of AVs on the roads while also preempting states from regulating AVs, are there minimum infrastructure conditions, design changes, or Vehicle-to-Infrastructure connectivity policies that need to be established at the national level? Should these changes be implemented before widespread deployment occurs?*

RESPONSE: Automakers and technology companies are designing and building automated vehicles to operate with existing infrastructure. While vehicle automation is likely to be supported by V2X systems, deployment of automated vehicles in the beginning is not dependent on V2X technologies. While establishing a national standard for V2V--as NHTSA was starting to do through its DSRC NPRM--would have quickly brought about broad industry adoption of a specific interoperable technology, some companies have moved ahead of the agency. ITS America members Toyota and Volkswagen have already committed to deploying DSRC V2X in Japan and Europe respectively. Toyota and General Motors have committed to deploy DSRC V2X in new cars over the next decade in the United States.

To optimize the performance of connected and automated vehicles while building intelligent infrastructure to compete in the 21st century technology-driven economy, upgrades to our nation's

infrastructure is needed. For example, we will need a 21st century, high-speed communications wireline infrastructure backbone, such as could support 5G along major transportation facilities to optimize vehicular communications. Though a national standard for a communications platform is an important component of ensuring that vehicles operate safely and efficiently across state lines, it is equally important to ensure that those infrastructure upgrades are in place to optimize deployment of connected and automated vehicles.

Congress could create a new program under the surface transportation law aimed at infrastructure upgrades in those areas that will be the testbeds for large-scale connected and automated vehicle deployment, or our nation's most heavily traveled regions and trade corridors. These near-term improvements should have the dual benefit of immediately improving the operation of our nation's' transportation system while also preparing it for connected and automated vehicle deployment. For example, the high-speed communications infrastructure backbone mentioned above will not just provide the basis for future vehicle-to-infrastructure communications but will also allow for the deployment of congestion-reduction technologies today such as current generation active traffic management, high-occupancy toll lanes, incident management and smart signal operations.

Additionally, from a transportation planning and policy perspective, how motor vehicles operate on public roadways have a significant impact on state and local abilities to make progress on their mobility, safety, performance, economic, environmental and social equity goals. As such, we believe that federal legislation should affirm the existing roles and maintain the balance of responsibilities between states, local governments, and the federal government in reference to the operation of automated vehicles.

4. In aviation and surface transportation settings, pilots and drivers must be certified to operate vehicles through a licensing process. Given the variation in how AV technologies operate and detect the roadside environment through probabilistic reasoning, should there be a similar licensing approach to certify that AVs are adequately prepared to detect the roadway signs, markings, infrastructural elements, and other users of the road? If yes, how so? If no, how might we otherwise ensure that in complex urban environments, for example, that highly autonomous vehicle technology is prepared to operate safely and effectively?

RESPONSE: Automotive innovation is occurring at a rapid pace and that innovation is advancing safety technology, including automated driver assistance systems, that help drivers avoid collisions. USDOT, under current and past administrations, wanted to encourage that innovation toward the goal of improved safety. There is variation in how automated vehicle technologies operate, which is how technology gets developed--different companies come up with different solutions to the same problem. An industry consensus approach and design for automated vehicle systems will emerge from iteration and evolving standards and best practices just as they emerged for past automotive technologies. A number of processes, checks and

balances are in place regarding the safe testing of automated vehicles, starting most importantly with a safety driver.

In addition, there are a number of industry standards and best practices for ADS-equipped test vehicles, including SAE J3018, Guidelines for Safe On-Road Testing of Level 3, 4, and 5 Prototype Automated Driving Systems (ADS). Manufacturers also conduct thorough simulation and closed-track testing, followed by real road testing with safety drivers. More generally, under the U.S. self-certification system for the regulation of automobiles, manufacturers must certify that any vehicle they put on the road must comply with all Federal Motor Vehicle Safety Standards (FMVSS) or that they have received an exemption from NHTSA determining the alternative means of meeting the standard is of an equivalent or higher level of safety. NHTSA continues to retain all of its enforcement authorities over the testing of automated vehicles on public roads, including random compliance testing of vehicles and recalling any vehicle or equipment it believes is unsafe. NHTSA has broad enforcement authority to investigate, penalize, and potentially mandate recalls involving automated vehicles. This is no different than its authority with respect to conventional motor vehicle components.

5. A significant number of roadway fatalities in this country occur on rural roads. One of the biggest challenges regarding the use of connected and automated vehicles is the lack of required infrastructure features to accommodate them in rural parts of the country. What can and should we be doing to prepare rural America for the expanded use of AVs?

RESPONSE: V2V communications technology can dramatically increase roadway safety, with the potential to eliminate 89% of Light Vehicle to Light Vehicle crashes and 85% of their associated economic costs. V2V technology is direct communication using the 5.850-5.925 GHz band ("5.9 GHz Band) between vehicles and does not require telecommunications infrastructure, such as cell towers, to function. The FCC allocated this 75 MHz of spectrum in 1999 for intelligent transportation services using DSRC and established licensing rules in 2004. Some automotive manufactures have begun or announced plans to deploy DSRC in vehicles. DSRC systems are designed to provide a short-range, wireless link to transfer information between vehicles and roadside systems. Recent advances in wireless communications technology have resulted in the development of Cellular-V2X ("C-V2X") solutions that are being tested globally and utilize the 5.9 GHz band for direct V2V communications. Both DSRC and C-V2X can support the capability of V2I communications using the 5.9 GHz band. As automated driving systems continue to advance, combining them with connected-vehicle technologies holds the potential to dramatically reduce traffic fatalities and injuries and to improve throughput on existing roads.

V2I technology requires the installation of road side units to communicate with vehicles and communications infrastructure to enable highway operators to achieve situational awareness of roadway conditions. V2I will allow highway operators to provide information to drivers of road hazards, traffic conditions, or weather events. Many states have announced plans for deploying smart highway infrastructure on urban highways and rural roads. For example, the Colorado Department of Transportation (CDOT) plans to deploy 245 roadside units (RSUs) by 2019. By the end of the decade, more than 500 miles of state highways will be outfitted with RSUs to

support V2I communication. Many of these state highways are in remote rural and mountainous areas that are difficult to cover with reliable cellular communications networks. Moreover, CDOT has committed to ensure that as significant improvements are made to Colorado's roadways network, the infrastructure needed to support V2I communication will be included in these projects.

ITS America believes deploying broadband infrastructure in conjunction with deploying V2I infrastructure could create significant synergistic benefits to rural America. Interstate highways located in rural areas are well suited for SAE level 1 systems like Driver-Assistive Truck Platooning (DATP), which are coming to market in the near term. Systems like DATP are designed to operate on existing multi-lane, divided, limited-access highways and require no new infrastructure or infrastructure changes. These systems improve the safety and efficiency of freight transportation by enhancing the teamwork between drivers while they navigate the roadway, allowing traffic to enter and exit the highway, reacting to potential cut-ins, and coordinating lane changes. Pairs of platooning trucks will be able to navigate the roadway and interact with other traffic just as other trucks do today. As part of ensuring the safe operation of driver-assistive truck platooning, system providers like Peloton Technology are using a combination of cloud-based monitoring and on-board sensors to only allow platooning on suitable highways and under appropriate weather and traffic conditions.

6. Truck platooning could be one of the earliest forms of automation technology to be broadly adopted on our nation's roadways. This technology allows trucks to run close to one another in a caravan formation. From an infrastructure perspective, this creates the potential for trucks to use roads more efficiently. On the other hand, bridges have been designed for greater spacing between heavy trucks, therefore more needs to be learned on whether bridge spans can safely handle the added weight. What research has been done into the impact that platooning could have on the structural integrity of our bridges? How many platooned trucks do you think most bridges could reasonably hold? Do you think there should be a limit to the number of vehicles allowed in a platoon in order to avoid this damage to our nation's infrastructure?

RESPONSE: From George Washington's interest in canals and commercial waterways, the history of development in the United States has often been linked to advances in commercial transportation. Truck platooning offer an intriguing option for further efficiency in freight movement.

For the vast majority of bridges on multi-lane, limited-access, divided highways, based on analyses conducted to date, experts expect little to no negative effects when two-truck platoons are traversing them in comparison to existing non-platooning truck activity. Just last year, the Florida Department of Transportation (FDOT) conducted a highway bridge analysis and found fewer than one percent would have negative effects from two-truck platoons at a spacing of 30 feet between two 80,000-pound trucks. Based on the same FDOT analysis, no Florida bridges would have an issue with 60 feet between two 80,000-pound trucks.

Based on the standard formulas and rules for truck weight and axle spacing, even three-truck platoons at 60 feet following distances would present no issue for these and other bridges or other infrastructure on the U.S. highway system.

Today, in slower traffic, larger groups of conventionally-driven trucks (more than three or four) cross bridges at relatively close distances. As a result, platooning does not represent a major change to conditions that today's infrastructure frequently handles.

For the more rare cases of highway bridges with special weight limitations, such bridges can be geofenced such that truck platoons open up spacing between the two trucks before crossing the bridge. In fact, since platooning systems can automatically increase spacing when crossing such bridges, this technology is better equipped to manage compliance than are conventionally driven trucks.

Truck platooning providers have also demonstrated the ability to specifically geofence other areas not suited for truck platooning such as toll plazas, construction zones, and any other special areas.

7. What should transportation planners begin doing now to accommodate AVs? How long will such planning and implementation require?

RESPONSE: Planners can be an important part of the dialogue with the public on the safety and mobility benefits for automated vehicles. The first step they can take is to become educated on the precise status of the technology and how it fits or conflicts with current infrastructure and other transportation assets. Second, they can offer a clear assessment at the practical local level of what changes are necessary to realize gains from the technology in terms of safety. Third, they can increase their collaboration with the technical staff at state and local agencies dealing with traffic signals, utilities and telecommunication to understand the planning implications. Finally, they can begin now to amend longer range plans to include of the potential for increased automated vehicle availability and travel. Even if these are simply presented as options, they will help raise the possibility and the potential benefits in the minds of policy makers and the public.

Connected autonomous vehicle fleets have the potential to deliver significant mobility, safety, economic and environmental benefits. For example, connected and automated vehicles could increase the capacity of roadways to ease congestion by less lost time at signals, smoother traffic flow on highways and shorter distances between vehicles. On the flip side, automated vehicles could increase the amount of vehicle miles traveled and, depending on whether or not zero-emission technology is deployed in conjunction with automated technologies, increase greenhouse gas emissions. Transportation planners should acknowledge this uncertainty and focus on prioritizing infrastructure projects, programs and policies that will be effective across multiple potential future scenarios.

ITS America Board Member Metropolitan Transportation Commission (MTC), the metropolitan planning organization for the San Francisco Bay Area, has recently undertaken Horizon, a new effort to plan for, and help shape, a range of possible connected and automated vehicle futures.

By expanding beyond traditional long-range scenario planning, which holds fixed certain transportation and land use assumptions, Horizon will help inform big questions facing the transportation industry, such as:

- Will connected automated vehicles substantially increase the vehicle capacity of existing highway lanes? If so, does it make sense to add additional physical capacity today?
- How might automation help solve the first-mile/last-mile transit challenge, reducing barriers to transit ridership? What type of investments are needed to get us there?
- What roadway investments could incentivize the shift to connected automated vehicles and expedite short-term safety benefits?

Ultimately, this effort could help planners analyze project performance across a range of different futures and lead to more informed project prioritization. Though the benefits may be significant, this planning effort requires substantial time and resources. Because it is a break from traditional planning, Horizon is a wholly separate effort that MTC will complete in advance of developing the region's federally mandated Metropolitan Transportation Plan update. Additional federal planning funds and flexibility to experiment with innovative initiatives like Horizon could support transportation planners in efforts to maximize the benefits of connected automated technologies.

There are a large number of unknowns (some listed below) about how automated vehicles will impact the transportation system, but one of the most important unknowns is the timeline for broad automated vehicle adoption. Planners therefore need to start monitoring the impacts and trends as they emerge so that appropriate planning responses can be quickly developed as soon as long-term impacts can be confidently assessed. Transportation planners need to be flexible in their planning outlook, develop more scenarios and quantify the effect of each of the plausible outcomes. Instead of setting a rigid timing horizon, the planning efforts should be continuous and nimble and focused on achieving desired outcomes.

One approach that ITS America Advocacy Trust Member Regional Transportation Commission (RTC) of Southern Nevada anticipates taking is to develop a flexible roadmap that identifies "trigger points" for when key planning-related decisions about the future of the region's transportation infrastructure need to be made. As the monitoring indicates that those important inflection points are approaching, the agency and its partners will be able to assess previous plans and ensure that the responses to the triggers are still appropriate and desired by the community. This approach should allow transportation planners to maintain a continuous, cooperative, and comprehensive planning process related specifically to automated vehicles and other emerging technologies.

Among the potential impacts of automated vehicles that transportation planners need to monitor and prepare responses for:

- Increased VMT due to relocation or circulation of empty vehicles, traveling to pick up other passengers, to avoid paying parking fees, or for other types of logistical reasons.

- Increased VMT due to reduced impacts of travel time inefficiencies. As automated vehicles allow drivers to spend time in the vehicle on other activities (entertainment, work, etc.), the time cost of driving will be reduced, which will generally result in increased vehicle travel.
- Increased VMT due to expanded land development. Because the travel experience in automated vehicles will be less demanding on drivers (potentially even giving them
- productive work time during the commute), they may be more willing to travel longer distances between work and home. If this trend emerges, it would probably trigger increased sprawling development to reach cheaper land further away from urban/suburban regions.
- Automated vehicles may decrease use of active travel modes like walking and bicycling. Similarly, to how riding in a car may become easier and more appealing, some people may be more inclined to let their car drive them to nearby destinations, rather than choose to walk or bike.
- As automated vehicle technology works into transit vehicles and drivers are replaced, the costs of operating those vehicles will probably decrease. This may create a windfall that could be applied to lower fares or service expansions, potentially increasing transit use.
- A future with wide automated vehicle adoption may transform the ways in which current components of the transportation system are used. For example, TNCs (Lyft, Uber, etc.) will require more access to curb space as they grow in overall use, which may result in different sidewalk and curb designs, different regulations about temporary loading zones, or even different revenue streams from "curb fees."
- The need for extensive surface parking lots may be substantially reduced, as shared automated vehicles drop off passengers and leave for their next fares, or private automated vehicles relocate themselves to fringe areas with lower or no parking fees. If this trend materializes, parking areas in denser built environments (e.g., urban cores) could be converted to more productive uses and increase tax bases.
- Traffic congestion may be reduced if automated vehicles are able to operate more efficiently than conventional vehicles. Because automated vehicles may react faster than a human and be capable of operating safely with much smaller gaps between vehicles than human drivers may, road capacity could potentially increase. Current estimates of this additional "virtual" capacity range from about 50% to 400%. Such an increase in efficiency and traffic capacity of roads could potentially reduce the need for additional road or highway capacity (although other improvements to those facilities may be needed to achieve these capacity improvements). Over the long run, the need for some existing capacity may even decrease, potentially opening up right-of-way or current roadway areas for new and beneficial uses (e.g., parks, housing, etc.).

One important area that transportation planners need to immediately begin improving is the transportation modeling process, so that the models we use to determine whether, where, and when to add new infrastructure are effective at incorporating the wide range of potential traffic, behavioral, and economic changes that automated vehicles will bring.

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8. In Japan, the Japanese government is leading testing of AVs, which is currently restricted to major limited access highways rather than on urban streets. In testimony for this hearing, we also heard from both the Wyoming Department of Transportation and New York City Department of Transportation about their implementation of a USDOT pilot program that explores connected vehicle application concepts within a limited, specific pilot sites for a finite duration. This allows the agencies to assess the impacts and evaluate the benefits. What are the pros and cons of taking what could be considered a more limited approach?

RESPONSE: Automated vehicles are being tested on public roads in limited Operational Design Domains (ODD) where local and states in cooperation with the localities and in conformance with any requirements. The model of automated vehicles will not be ubiquitous personally owned AVs anytime soon. Rather it will be the roll out of shared mobility fleets in those communities where extensive testing has occurred.

Senator Whitehouse:

9. As our vehicles move towards automation, this change will require that our infrastructure and roadways are updated to ensure that autonomous vehicles operate safely and efficiently. Upgrades could include well-marked lanes, accurate signage, and traffic lights that can communicate easily and clearly with autonomous vehicles.

a. What type of upgrades and investment should we be making now to our existing roadways and infrastructure to accommodate autonomous vehicles?

RESPONSE: Near-term investments in our transportation system should provide benefits across an array of different scenarios. One example of such a resilient strategy is investment in a 21st century, high-speed communications infrastructure backbone, such as broadband and 5G, along major transportation facilities. Robust communications will not just provide the basis for future vehicular communications but will also allow for the deployment of congestion-reduction benefits today through active traffic management strategies like high-occupancy toll lanes, incident management and smart signal operations. Demonstration projects should be funded in conjunction with these near-term investments to test how to maximize the co-benefits of improving existing operations of major arterial roadways and preparing them for future connected and autonomous vehicle fleets.

Connected automated vehicles should be tested in real-world settings in a collaborative process that includes state and local governments. This applied testing will help best identify the scope of infrastructure investments that will be needed to maximize the benefits and manage the impacts of connected and automated vehicle technologies across different types of roadways and operational contexts. It is important that such testing occur in metropolitan regions, as well as in less dense areas, given that connected automated vehicles will ultimately need to cross jurisdictional lines, transition from major arterials to local roads, and navigate buses, motorcycles, electric scooters, bicycles and pedestrians, and delivery trucks stopped at loading zones. Investments likely will include traditional transportation improvements like re-striping

roads and upgrading signage along with investments in smarter infrastructure and data sharing technologies. For example, locals may need to share information on road closures, incidents and traffic signal operations with connected automated vehicles.

b. Should we be making changes to our infrastructure and roadways with the intention that the vast majority of vehicles in the future will be autonomous?

RESPONSE: Automakers and technology companies are designing and building automated vehicles to operate with existing infrastructure. We should be making changes to our

infrastructure and roadways with the intention of benefitting all users, improving accessibility and mobility, and achieving a state of good repair for our infrastructure. We should prioritize strategies that will benefit users regardless of the ultimate level of connected automated vehicle penetration rates.

c. If electric vehicles make up the vast majority of autonomous vehicles, what type of infrastructure changes will we need to facilitate this transition?

RESPONSE: In addition to state of good repair investments in roadways and new communications networks, we will need zero-emission vehicle charging infrastructure and utility capacity in order to facilitate deployment of zero-emission connected automated vehicle fleets.

10. Transportation is now the largest source of carbon emissions in the United States, and carbon emissions from cars and light trucks account for almost one-sixth of the nation's total emissions. We should be implementing policies in this sector with an eye towards reducing our emissions.

a. How can we design the right policies so that autonomous vehicles that enter our roadways are fuel-efficient and help us reduce our transportation emissions?

RESPONSE: Given the clear decision of developers and manufacturers to use electric or hybrid engines in automated test vehicles, it seems safe to say their actual deployment will contribute to emissions as well as safety and mobility policy objectives. The emissions and environmental benefits may be helpful selling points for a wary public unsure about "driverless" technology.

Federal, state and local governments could play a significant role in ensuring connected and autonomous vehicles are low-emitting. Policymakers could coordinate with utility providers to create blueprint and investment roadmaps for passenger, transit, and goods movement fleet charging and could consider incentives for investment in charging infrastructure to accompany other infrastructure improvements.

There is a natural synergy between automated vehicles and electric vehicles, ranging from compatibility in the power supply of electric drive technology with the electricity requirements for the additional vehicle hardware necessary for autonomous operations, to achieving weight, safety, and other co-benefits for vehicles specifically designed for electric drivetrains-related.

For automated vehicles to reduce transportation emissions, policies should be developed that encourage both the manufacturer and consumer use of automated vehicles that are powered by electricity. A wide variety of incentives for the manufacture of automated vehicles have been evaluated over the past decade and could be implemented.

b. Do we know how autonomous vehicle adoption will affect overall traffic patterns and the number of miles driven by cars? If not, what is the best way to study and better understand this?

RESPONSE: While connected and automated vehicle technologies should increase roadway capacity, they could also increase vehicle miles traveled. This is why we should consider travel

demand management policies (including pricing on our highways, parking, and curb space) as well as standardizing data systems. Specifically, mobility could be improved through dynamic road pricing. Connected automated vehicle proliferation is likely to bring a multitude of new mobility services and demand to the road network. Vehicle trips could be subject to dynamic road pricing schemes like variable pricing in high demand areas (e.g., congested corridors and urban downtowns) and enhanced and increased express lanes. Not only will this fairly price mobility, it will also cause cascading effects such as encouraging more shared trips. Importantly, dynamic pricing requires real-time connectivity between vehicle or service operators and network operators. To establish secure, efficient connectivity for these purposes, data sharing standards and protocols will need to be collaboratively created.

It is also important to consider that preparing for a connected automated future does not just mean focusing on traditional passenger vehicles and roadways. The desired policy outcome should be to expand access to high-quality transportation, which also means a significant reinvestment in mass transportation with trunk line rail and bus upgrades (including considering appropriate connected and automated technology upgrades that could improve service efficiency and effectiveness), connected and automated microtransit services, mobility-as-a-service platforms, and new funding mechanisms to support investments.

If automated vehicles are widely adopted, but not electrified using renewable energy or car sharing fails to take off, greenhouse gas emissions and air pollution could actually increase. A study last year by University of California, Davis researchers projected that if vehicles are automated but not electrified or shared, greenhouse gas emissions from the transportation sector would go up 50 percent by 2050 compared to business as usual. However, if shared, electrified, automated vehicles flourish, greenhouse gas emissions could plunge by 80 percent, the study concluded.

For automated vehicles to work, transportation planning agencies should develop policies that promote ridesharing, encourage electric powered vehicles, and institute parking fees/reduction in the number of parking spaces per vehicle. Electric vehicles (EVs) have the potential to reduce emissions, while ridesharing can reduce VMT. However, if ridesharing doesn't materialize but automated vehicles do, the result could be more traffic congestion, more vehicle miles traveled, and more emissions.

An important part of the development is commercial rather than technical. Developers need to explore what options and arrangements work for consumers and especially people who will share rides and vehicles. The pull of old habits for single-occupancy vehicle use remains strong, and new alternatives must be appealing and effective. There are numerous alternative scenarios for vehicle ownership and use. The benefits of reduced emissions and mitigating traffic congestion are easier to reach when individual drivers shift to shared ridership. Transportation planners need to be flexible, develop more scenarios and quantify the effect of each scenario's possible outcomes.

Regarding truck platooning, SAE Level 1 (Driver-Assistive Truck Platooning systems are likely coming to market later this year, which will improve the safety and efficiency of freight

transportation in the near term without the need for changes to today's infrastructure or normal flow of traffic.

Truck platoon providers like Peloton Technology use linked safety systems to allow closer following distances between trucks, resulting in aerodynamic fuel savings. At 65 mph, fuel savings across a two-truck platoon are 7.25%, based on testing by the North American Council for Freight Efficiency – 4.5% for the lead truck and 10% for the follow truck. Along with "connected braking" – which bypasses delays in human perception and reaction time – a safe following distance of trucks in platoon is maintained by ordering the truck with the longer estimated stopping distance as the lead truck. This significant fuel savings is a win-win for fleets and the environment. Truck platooning can also deliver benefits for trucks with electric, hybrid or natural gas powertrains by providing range extension for these trucks -- thus expanding the use-cases where fleets can make use of these types of trucks and accelerating the adoption of low or zero-emissions truck powertrains.

11. Reports suggest that the autonomous vehicle industry could expand into the trucking industry, e-hailing, and ride-sharing industry.

a. How soon can we expect widespread adoption of autonomous vehicles in these industries?

RESPONSE: Companies are on track to develop and produce fully autonomous vehicles for commercial use over the next few years. Time will tell how quickly these vehicles will be widely adopted.

b. How can we get ahead of the potential job losses that could occur in traditional trucking and ride-sharing industries if autonomous vehicles are widely adopted?

RESPONSE: Autonomous vehicles have the potential to reduce transportation and logistics operating costs for trucking, transit and the private mobility-as-a-service and delivery industries, improving efficiencies and adding to economic prosperity. However, automated vehicles could cause job loss for workers currently employed in trade, transportation, and utilities industries. It

is important to note that, much as smartphones introduced a wide range of previously inconceivable business models and disrupted decades-old industries, from cameras to calculators, connected and automated could introduce unforeseeable consumer products and services with a wide range of implications for the retail, service, and information industries. This economic shift could give birth to new industries with new opportunities.

Policy makers should consider targeting industrially-zoned lands for production, distribution, and repair. Once mainstreamed, the technology is likely to have an agglomeration effect, spurring other supportive industries like connected and automated vehicle production, distribution, and repair, all requiring physical space and resources. Local policy makers should work to ensure these trends benefit the whole community in part by zoning for manufacturing, distribution, and other industrial uses.

Lastly, government should be piloting connected automated vehicle applications that could spur new job opportunities. Even though much connected automated innovation is focused on the passenger economy, opportunities in goods movement are significant. Government agencies should launch competitions and support pilot programs in connected automated vehicle logistics, including sidewalk robots, drone delivery, modular urban logistics systems, and truck platooning.

c. *Do we need to consider job retraining and workforce development policies to ensure that autonomous vehicle deployment does not disrupt the job markets for taxi, bus, and shuttle drivers?*

RESPONSE: Training programs should be strengthened to expand opportunities for workers in the automated vehicle industry. As demand for drivers drops, thousands of workers may no longer be needed. In the interim, significant driver shortages are possible as workers retire, recruitment stagnates, and mobility demand continues to rise. Enhanced training programs could build skills in related growing fields such as customer service, data analytics, and specialized mechanics.

In addition, new investments in transportation, communications and zero-emission vehicle charging infrastructure will create near-term job opportunities.

The truck technologies coming to market today, such as truck platooning, are focused on using connectivity and advanced driver-assistance to improve safety, efficiency and mobility. These solutions do not displace driver jobs but instead improve driver jobs by helping them be safer and more productive. In the freight market today, fleets cannot find enough drivers to meet the growing demand. In a report from last year, the American Trucking Associations projected a driver shortage of 50,000 in 2017, increasing to almost 175,000 by 2026 under current trends. Anyone who wants to drive a truck today should have no problem finding a job and keeping it for decades, even with automated trucks starting to arrive in the market.

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Even when large numbers of driverless trucks are on the road, there will be opportunities within the trucking industry for jobs that could pay more than drivers make today as well as new trucking-related jobs -- some already envisioned and others that no one has even thought of yet.

Truck automation will only enter certain segments of trucking operations over the next decades. Therefore, thoughtful projections show that increased truck automation can simply allow drivers to move from the hardest, least desirable jobs to healthier, better jobs.

A number of projections show that by increasing automation in trucking, the trucking industry could better handle skyrocketing freight volumes, which could lead to a net increase in total driver jobs -- with the most growth in more desirable local and regional haul driving. More and better driver jobs will exist in the future.

In the meantime, it is important for industry, drivers, and other stakeholders to have a meaningful dialogue about what the future holds. This should include a careful examination of how existing job training opportunities could help future drivers adjust to a world with AVs or what new training programs for the future workforce need to be developed and adequately funded.

A good first step is that industry leaders are beginning to study what a possible workforce of the future will look like, which will better inform the dialogue with the driver community and the public.

We know that over time, autonomous vehicles will change occupations in ways that require more skills and retraining. In the short term, the number of net jobs available will increase to support autonomous vehicle testing and fleet operations. We need to identify the new jobs that will be created, and industry has already started down this path. Several job classifications will not require a college degree, but training is critical. It will be important to coordinate with all levels of government to ensure technical and education programs align with the job needed to be done. Outreach efforts at the local level is key to getting the word out about new job opportunities in an automated vehicle era.

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Senator BARRASSO. Thank you very much, Mr. Bhatt. We appreciate your being here.

Mr. Doerzaph.

STATEMENT OF ZACHARY DOERZAPH,
DIRECTOR, CENTER FOR ADVANCED AUTOMOTIVE RESEARCH

Mr. DOERZAPH. Chairman Barrasso and members of the Senate Committee on Environment and Public Works, at BTTI we conduct research for many public and private organizations on automated systems that are infrastructure and the people who own, operate, and ride within them. It is an honor to be here to discuss this very important topic with you. I am quite passionate about it myself.

Automation may indeed substantially one day have a positive impact on transportation safety and efficiency. However, exceeding the capability of the human driver is extraordinarily difficult and is currently underestimated by many. To achieve the same safety benefit as the best 10 percent of drivers, automated vehicles, for all practical purposes, can never virtually crash.

Large scale deployment of automated vehicles will take decades to achieve, and there will be a significant percentage of manually driven vehicles for the foreseeable future. Automation remains costly, does not equally benefit all users, and does not operate ubiquitously across all environments.

Fortunately, though, automated vehicles are very much being designed to operate on roadways that were created for human drivers. As with humans, the reliability of those automated systems depends on things like roadway design quality, lane markings, signs, and other traffic control devices.

At the same time, though, specific infrastructure elements do create particular challenges unique to automated vehicles. These edge and corner cases, as we call them, pertain to things like work zones and emergency situations, adverse weather, and anywhere that humans can exchange a simple nod, glance, or hand wave in order to communicate with another road user, which is where connected vehicle technologies come in. These technologies, which allow vehicles to communicate with other vehicles, as well as the infrastructure and other road users, provide an additional mechanism for improving the perception, recognition, path planning processes for automation, resulting in safer and more efficient systems overall.

Connectivity also enables this proactive conversation to take place between vehicles and vehicles in infrastructure, much like humans do today.

So, in conclusion, I believe there are measured actions that should be taken by all stakeholders based on careful planning to exercise that safety is maintained throughout the evolution and deployment of automated vehicles, and I recommend doing so through the following approach.

Support partial automation today. These are systems which are compatible with the infrastructure, and when appropriately designed, these limited automations, such as emergency automated braking, lane keep assist, and others, improve safety and reduce congestion by leveraging the strengths of both the human and the machine.

The Federal Government can play a role in providing a clear pathway to increasing levels of automation with appropriate operational domains based on demonstrated success.

I also believe we need to incentivize precompetitive collaboration between individual companies, as well as between those companies and the road operators, to collaboratively overcome the technology and policy hurdles.

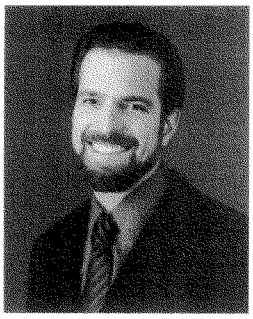
We also need to facilitate the mechanisms for automated vehicles to report road deficiencies back to the operators so that we have a closed loop cycle of improving those facilities. We need to provide the resources and guidance required to improve our physical and digital infrastructure through applied research and deployment support.

Connected technologies require a robust, nationally interoperable back end data system, precise vehicle localization, and accurate infrastructure information across city, State, and local borders. It is imperative that security mechanisms which establish digital trust and identify and remediate threats are in place.

We also need to facilitate a broad dialogue and correlation to define the appropriate oversight role for the Federal and State public agencies to develop mechanisms for monitoring and updating such oversight in order to balance innovation with public safety based on objective measures.

And finally, I would be remiss if I did not mention that I believe we need to maintain this pace of innovation by facilitating next generation transportation work force through technology focused multidisciplinary education and by supporting a variety of programs for students at all levels.

[The prepared statement of Mr. Doerzaph follows:]



Dr. Zachary Doerzaph
Director
Center for Advanced Automotive Research

Dr. Zachary Doerzaph is the Director of the Center for Advanced Automotive Research at the Virginia Tech Transportation Institute (VTTI) and is an associate professor with the Department of Biomedical Engineering and Mechanics at Virginia Tech.

Dr. Doerzaph coordinates a research portfolio focused on measuring and improving the performance of next-generation vehicle systems. His research projects emphasize safety as it relates to the interactions between the driver, vehicle, and infrastructure. He focuses his efforts on the design, development, and evaluation of connected vehicles, collision avoidance systems, automated driving systems, driver interfaces, and driver behavior monitoring and evaluation. Dr. Doerzaph prepares future transportation engineers for careers in the rapidly evolving transportation sector via hands-on industry engagement and traditional coursework. His team of faculty, staff, and students are currently working on a variety of technologies that will improve transportation for all users both in the near-term and into the future.

Testimony of Dr. Zachary Doerzaph, Director of the Center for Advanced Automotive Research at the Virginia Tech Transportation Institute (VTTI) and Associate Professor of Biomedical Engineering and Mechanics at Virginia Tech

Chairman Barrasso, Ranking Member Carper, and members of the Senate Committee on Environment and Public Works:

I submit testimony as a transportation scientist and Director of the Center for Advanced Automotive Research at the Virginia Tech Transportation Institute (VTTI). At VTTI, we conduct research for many public and private-sector sponsors on automated systems, including vehicles, infrastructure, and the people who own, operate, and ride within them. It is my honor to discuss this important topic and to share the following observations with this committee.

Automation may eventually have a substantial positive impact on transportation safety and efficiency. However, exceeding the capability of human drivers is extraordinarily difficult and is currently underestimated by many. The average driver has one police-reportable crash approximately every 18 years of driving. The safest 10% of drivers—meaning those who remain alert, attentive, and sober behind the wheel—are 10 times safer than the average driver. Many of the safest drivers will go through a lifetime without experiencing a single serious crash. Thus, to achieve the same safety as the best drivers, automated vehicles can almost never crash.

Large-scale deployment of automated vehicles will take decades to achieve, and there will be a significant percentage of manually driven cars for the foreseeable future. Automation remains costly, does not equally benefit all users, and does not operate ubiquitously across all environments.

Fortunately, automated vehicles are designed to operate on roadways created for human drivers. As with humans, reliable automated-vehicle performance is related to the quality of road design, lane markings, signs, and other traffic control devices. Yet, specific infrastructure features can present challenges unique to automated vehicles. Such edge-and-corner cases include work zones, emergency situations, adverse weather, and anywhere that humans rely on a simple glance, nod, or handwave to communicate with other road users.

Connected technologies—including cellular and dedicated short-range communications—between vehicles and between vehicles and the infrastructure provide an additional mechanism for improving the perception, recognition, and path-planning processes for automation, resulting in a safer and more efficient system overall. Connectivity enables proactive collaboration between elements of the transportation network, thereby permitting quicker and more robust decisions.

In conclusion, automation may provide substantial improvements in transportation performance. However, measured actions by all stakeholders based on careful planning should be exercised to ensure that safety is maintained throughout the evolution and deployment of automated vehicles. Therefore, I recommend the following approach:

Support deployment of partial automation within compatible infrastructure. When appropriately designed, advanced driver assistance systems with limited automation, such as well-designed automated emergency braking and lane keep assist systems, improve safety and reduce congestion by leveraging the strengths of both human and machine. The federal government can help by providing a clear pathway to increasing levels of automation within appropriate operational domains based on demonstrated success.

Maximizing mobility benefits while improving safety for all users should be viewed as a nationally advantageous goal that we should work toward as a society rather than as independent competitors. It is not sufficient for automation to work most of the time; it must work nearly all of the time. It will take all of the stakeholders in the transportation system to attain this goal.

Incentivize precompetitive collaboration between individual companies and road operators to overcome technological and policy hurdles. Facilitate mechanisms for automated vehicles to report challenging infrastructure elements to road operators so that public investments may be appropriately prioritized.

Provide the resources and guidance required to improve our physical and digital infrastructure through applied research and deployment support. Connected technologies will significantly improve performance, but they require robust, nationally interoperable backend data systems, precise vehicle localization, and accurate infrastructure information across city, county, and state borders. Security mechanisms that establish digital trust and identify/remediate threats are imperative.

Facilitate broad dialogue and coordination to define the appropriate oversight role for federal and state public agencies. Develop mechanisms for monitoring and updating such oversight to balance innovation with public safety based on objective measures.

Finally, maintain the pace of innovation by facilitating the next-generation transportation workforce through technology-focused multidisciplinary education and by supporting a variety of programs for students of all levels.

Responses for Ranking Member Carper:

1. *Early, high-profile crashes of autonomous vehicles have sowed public concerns and potentially distrust of autonomous vehicle technology. What improvements to the infrastructure necessary to support autonomous vehicle technology must occur in order to ensure that deployment of AVs builds public confidence? Specifically, what steps can the EPW Committee take to ensure that infrastructure helps to support the safe operation of these vehicles?*

A positive public opinion is indeed a key factor for the success of automated vehicle systems. Some of the recent crashes have highlighted deficiencies with the current automated technologies, understandably reducing public trust and raising concerns for numerous stakeholders. To gain widespread acceptance, AVs must improve the traveler's experience while demonstrating consistently safe performance at both the individual and national levels. Altering the public's perception may be a challenge – an individual's perceived risk for an activity over which they have no control (i.e., riding in a highly automated vehicle) tends to be higher than one in which they feel in control (i.e., manual driving).

Even if we assume that forthcoming highly automated vehicles (HAVs) will be able to achieve near perfect safety, there may remain an insufficient number of these vehicles on the road to demonstrate their safety capabilities to the public. A single high-profile severe crash, even if such a crash rarely occurs, could quickly undermine public trust given most people's extremely low exposure to HAVs. Thus, I believe a stepwise approach to incrementally establishing public trust starting with lower levels of automation is better than focusing on the handful of prototype HAVs currently being tested on the roadway.

The EPW can support public acceptance by promoting the success of automated collision avoidance systems, which currently demonstrate safety benefits via their ability to leverage both human and machine capabilities. Indeed, our research has shown that drivers are supportive of collision avoidance systems when they play an active role in mitigating or eliminating what would have otherwise been a crash. Exposure to systems which help drivers maintain appropriate following distances (adaptive cruise control) and stay within an appropriate driving path (lane keep assist) will further help to build consumer experience and trust in automated systems. This trust can be incrementally increased until HAVs are truly ready for the public. Furthermore, the steps that I have outlined below to support current and next generation partially automated systems will also support the needs of HAVs as they come online.

Specifically, to support the safe operation of AVs at all levels, I suggest the EPW consider focusing on the following three areas:

- Promote and provide resources to improve the state of repair across the infrastructure. A particular focus on the condition and visibility of traffic control devices, such as lane lines and signage, are of particular interest, as these remain critical to conveying the rules of the road to both humans and automated driving systems.

- Establish a robust, interoperable, secure, and private connected vehicle system to enable digital collaboration between road operators, data providers, and all road users, including AVs, for sharing information such as:
    - Verified real-time map data, which remain updated even in dynamic areas such as work zones and other variable roadway environments where AVs tend to fail.
    - Signal phase and timing information to optimize an automated vehicle's safe intersection approach and coordinate signalized intersections with forthcoming traffic to improve safety and efficiency.
    - Traveler and roadway information to both improve situational awareness of the hazards ahead and to enable road operators to broadly exercise active traffic management capabilities (e.g., variable speed limits, queue detection, lane closures, etc.) aimed at improving safety and traffic flow across roadway networks.
- Support collaborative research to:
    - Better understand the needs of infrastructure to ensure the safe operation of automated vehicle systems.
    - Develop and test infrastructure systems which supports such needs.
    - Facilitate deployment of large numbers of increasingly capable AVs within confined environments to investigate the full range of research questions related to AV safety.

2. *Given that the House and Senate AV bills provide NHTSA with new exemption authority to permit thousands of AVs on the roads while also preempting states from regulating AVs, are there minimum infrastructure conditions, design changes, or Vehicle-to-Infrastructure connectivity policies that need to be established at the national level? Should these changes be implemented before widespread deployment occurs?*

In general, AVs have been developed to work on the same roadways designed for humans and to benefit from the same basic treatments (e.g., guardrails, visible signs, etc.). However, to maximize the safety of HAVs, infrastructure should be updated to meet current national roadway standards with the goal of creating a consistent environment for perception and recognition systems. When feasible, facilities dedicated to AVs may allow for their operation sooner. Such facilities would control risk by isolating other types of road users and employing additional roadside safety hardware, such as barrier systems, which can reduce the severity of crashes and associated injuries.

Widespread use of vehicle to infrastructure communications (V2I) could be a significant enabler for automated systems. For this to occur, V2I must become broadly available, robust, interoperable, secure, and private. In addition to improving safety by providing dynamic information about the roadway environment, V2I should also be leveraged as a mechanism for direct collaboration between road operators and vehicles. This will, for example, allow AVs to report challenging infrastructure to road operators, who can then initiate an investigation and apply treatments as appropriate. One of the primary reasons we do not have a complete understanding of how infrastructure can impact automated vehicle performance is that we lack mechanisms for vehicle-to-operator reporting.

3. *In aviation and surface transportation settings, pilots and drivers must be certified to operate vehicles through a licensing process. Given the variation in how AV technologies operate and detect the roadside environment through probabilistic reasoning, should there be a similar licensing approach to certify that AVs are adequately prepared to detect the roadway signs, markings, infrastructural elements, and other users of the road? If yes, how so? If no, how might we otherwise ensure that in complex urban environments, for example, that highly autonomous vehicle technology is prepared to operate safely and effectively?*

This question focuses on an area of considerable uncertainty within the research community. With today's technology availability, we are in a period where automation may be developed by a broad array of organizations and individuals of varying capabilities and safety cultures. As such, we need a mechanism in place to ensure automated innovations move us forward while also ensuring public safety. Given the system complexity and diversity of operational environments, we have yet to determine whether a licensing approach to certifying AVs would make certain appropriate safety is achieved.

In order to guarantee the desired level of safety, a first step in this process is to translate the Federal Motor Vehicle Safety Standards for highly automated driving systems. NHTSA's *A Vision for Safety* also provides an important starting point for outlining key safety areas that would need to be considered. As a safety community, we need to collectively establish recommended practices that pull together the current body of knowledge to establish reasonable assessment approaches and metrics that are technology agnostic and performance based. These may include a combination of controlled testing, simulations, and field evaluations.

Due to the complexity of automation and the trend toward systems that evolve after deployment (whether by machine learning or remote software updates), ongoing vehicle monitoring may also be required. There should be a research focus on developing real-time analytics capabilities that efficiently capture critical performance data elements which inform manufactures, owners, operators, and other stakeholders and enable early identification and remediation of deficiencies.

In addition, NHTSA should continue to have a strong enforcement authority and management of the recall process. NHTSA may need additional resources to address the added complexity of AVs while maintaining their oversight of legacy vehicles.

4. *A significant number of roadway fatalities in this country occur on rural roads. One of the biggest challenges regarding the use of connected and automated vehicles is the lack of required infrastructure features to accommodate them in rural parts of the country. What can and should we be doing to prepare rural America for the expanded use of AVs?*

In rural areas, V2I may be difficult to achieve due to a lack of roadside connectivity. This creates additional demand for rural broadband efforts, including reliable cellular network technologies, which can help road operators connect infrastructure components inexpensively. Rural roads, which may be built to older standards, also have significant vertical and horizontal curvature, unmarked lanes, and less frequent maintenance schedules, all of which may pose a challenge for automated vehicle systems. The EPW could provide road operators with additional resources to

bring rural roads up to modern standards and allow more frequent maintenance cycles, which will help both human drivers and automated driving systems navigate the region safely.

5. *Truck platooning could be one of the earliest forms of automation technology to be broadly adopted on our nation's roadways. This technology allows trucks to run close to one another in a caravan formation. From an infrastructure perspective, this creates the potential for trucks to use roads more efficiently. On the other hand, bridges have been designed for greater spacing between heavy trucks, therefore more needs to be learned on whether bridge spans can safely handle the added weight. What research has been done into the impact that platooning could have on the structural integrity of our bridges? How many platooned trucks do you think most bridges could reasonably hold? Do you think there should be a limit to the number of vehicles allowed in a platoon in order to avoid this damage to our nation's infrastructure?*

The structural integrity of the nation's bridges is not within my area of expertise and thus my knowledge on this topic is limited. However, reduced headways in heavy vehicle platoons increases bridge loading, which may exacerbate wear. Given that ASCE rates 9% of the nation's bridges as structurally deficient, a thorough research program focused on this topic may indeed be warranted.

It is also possible that truck platoons could have other unique impacts on infrastructure that are currently not well understood. For example, we are investigating the performance of roadside safety infrastructure components (e.g., guardrails) when they are impacted by a platoon. Initial results indicate that existing infrastructure will not provide the desired protection to all occupants when crashes occur. Similarly, we are conducting a related project investigating whether AVs will increase pavement rutting as a result of their potential to retain more consistent lateral position within the lane, thus concentrating loads over a smaller region. The EPW should continue supporting research analyzing the impacts of AV on infrastructure such that requirements and policies can be put in place to mitigate threats to safety.

6. *What should transportation planners begin doing now to accommodate AVs? How long will such planning and implementation require?*

Transportation planners should consider a range of potential AV deployment models based on reasonable assumptions in their locality. Resources should be focused on the areas where overlap across these models is identified, reducing the likelihood of wasted effort. Planners must remain flexible to a rapidly changing environment and be able to move resource allocations swiftly as technologies and deployment strategies change. For the foreseeable future, planning will be an ongoing process with no clear timeline for widespread implementation of AVs.

7. *In Japan, the Japanese government is leading testing of AVs, which is currently restricted to major limited access highways rather than on urban streets. In testimony for this hearing, we also heard from both the Wyoming Department of Transportation and New York City Department of Transportation about their implementation of a USDOT pilot program that explores connected vehicle application concepts within a limited, specific pilot sites for a finite duration. This allows the agencies to assess the impacts and*

evaluate the benefits. What are the pros and cons of taking what could be considered a more limited approach?

As indicated by current industry testing, pilot deployments can be a powerful tool for evaluating new technologies within a more controlled region. Plot deployments allow developers to carefully monitor system performance and rapidly refine systems as lessons are learned. There is an opportunity for much larger partnerships to substantially increase the penetration rate of HAVs to a level where more robust conclusions can be obtained by stakeholders.

For example, as the technology matures, partnerships between the industry, federal government, state governments, researchers, and communities should allow the collaborative deployment of AVs. With sufficient scale, system-wide impacts can be evaluated at a level that enables researchers to investigate safety, mobility, and environmental advantages with unprecedented accuracy. Analyzing the performance and use patterns of AVs within these deployments will allow researchers to begin reducing the number of assumptions present in the planning models and permit all stakeholders to more appropriately allocate resources to promote AV proliferation as appropriate.

The downside of pilot deployments is the concentration of resources on a limited region. This focus may reduce available resources for other regions and limit the breadth of environments in which the research is conducted. In addition, a limited number of large profile pilot deployments may focus the public's attention on only a few key efforts. This, in turn, may limit the public's direct exposure to a wider base of automated technologies and could undermine acceptance if a high-profile pilot program is unsuccessful.

Responses for Senator Whitehouse:

8. *As our vehicles move towards automation, this change will require that our infrastructure and roadways are updated to ensure that autonomous vehicles operate safely and efficiently. Upgrades could include well-marked lanes, accurate signage, and traffic lights that can communicate easily and clearly with autonomous vehicles.*
    a. *What type of upgrades and investment should we be making now to our existing roadways and infrastructure to accommodate autonomous vehicles?*

As discussed within my response to Ranking Member Carper's first question, I recommend the following infrastructure updates:

- Promote and provide resources to improve the state of repair across the infrastructure. A focus on the condition and visibility of traffic control devices, such as lines and signage, are of particular interest.
- Establish a robust, interoperable, secure, and private connected vehicle system to enable digital collaboration between road operators, data providers, and all road users, including AVs.
- Support collaborative research to:
    - Better understand the needs of infrastructure for supporting AVs.
    - Develop and test infrastructure systems which support such AV needs.
    - Facilitate deployment of large numbers of increasingly capable AVs within confined environments to investigate the full range of research questions related to AV safety.

    b. *Should we be making changes to our infrastructure and roadways with the intention that the vast majority of vehicles in the future will be autonomous?*

While the progress of AVs is unprecedented, humans will continue to play a vital role in the driving task for some time. Therefore, most broad near-term infrastructure updates should focus on systems that benefit both human and machine drivers. As indicated within my original testimony, HAVs have not been proven safe, remain costly, don't benefit all users equally, and do not operate ubiquitously across all environments. Furthermore, even when they become readily available, widespread deployment of HAVs is likely to take a decade before broad adoption. Fortunately, AVs are being designed to work on roadways designed for human drivers. The updates I have recommended will benefit human drivers, particularly those with advanced driver assistance systems (advisories, warnings, and partial automation), just as they will help HAVs.

    c. *If electric vehicles make up the fast majority of autonomous vehicles, what type of infrastructure changes will we need to facilitate this transition?*

While vehicle electrification is not within my primary area of expertise, the availability of public rapid charging infrastructure along with clean energy sources and updated distribution systems are some of the infrastructure improvements that may be necessary to support broad adoption of electric vehicles.

9. *Transportation is now the largest source of carbon emissions in the United States, and carbon emissions from cars and light trucks account for almost one-sixth of the nation's total emissions. We should be implementing policies in this sector with an eye towards reducing our emissions.*
    a. *How can we design the right policies so that autonomous vehicles that enter our roadways are fuel-efficient and help us reduce our transportation emissions?*

From my viewpoint, all vehicles should be considered within existing and future policies pertaining to fuel efficiency and clean emissions. While more research specific to AV impacts on emissions is warranted, I do not see an immediate need to deviate from the existing mechanisms available to policy makers for controlling fuel efficiency and emissions.

    b. *Do we know how autonomous vehicle adoption will affect overall traffic patterns and the number of miles driven by cars? If not, what is the best way to study and better understand this?*

Numerous studies have modeled various possible scenarios in a highly automated vehicle future. There is not a consistent trend indicating how AV adoption will impact traffic and vehicle use patterns, likely due to variability of the underlying assumptions adopted by any given effort. As the technology develops and we can refine assumptions or replace them with validated observations, the models should start to converge – providing us with more robust estimates. Thoughtfully designed pilot deployments and associated analyses will help provide the information needed to improve these models.

10. *Reports suggest that the autonomous vehicle industry could expand into the trucking industry, e-hailing, and ride-sharing industry.*
    a. *How soon can we expect widespread adoption of autonomous vehicles in these industries?*

It is important to note that AV systems, such as collision avoidance technologies, adaptive cruise control, and lane keep assist, are already in use within all of the aforementioned industries. These systems, which are demonstrating measurable safety benefits, will continue to proliferate as price decreases, capabilities increase, and more users perceive their benefits.

Low speed automated transit vehicle shuttles are being deployed across the country. While most of these vehicles still currently have a safety driver, it is likely that such drivers will not be required in the coming years. These shuttles may represent some of the first widespread use of HAVs and will be able to provide effective transportation over short distances in relatively well controlled environments.

Industries that aim for high levels of automation across a broad range of environments will take longer to mature such that I cannot provide a reliable time estimate. Because of the diversity of environments and higher speeds, these industries should achieve a very high reliability prior to moving into the deployment phase. For example, the best highly automated vehicle prototypes, which tend to drive on a limited number of roadways in relatively good weather, are reporting

~6,000 miles between safety driver interventions. These interventions demonstrate that HAVs are still reliant on the human and suggest that we have yet to create a robust system, much less a level of safety at which broad public acceptance will be achieved.

b. *How can we get ahead of the potential job losses that could occur in traditional trucking and ride-sharing industries if autonomous vehicles are widely adopted?*

I have not studied this complex issue and opt not to provide a response so as not to inadvertently provide inaccurate information.

c. *Do we need to consider job retraining and workforce development policies to ensure that autonomous vehicle deployment does not disrupt the job markets for taxi, bus, and shuttle drivers?*

I believe workforce development is a valid focus given the rapidly expanding AV industry. One example of a current effective educational mechanism supported by the federal government is the University Transportation Centers (UTC) program. The UTC provides funding for research, technical transfer, and workforce development activities. The committee should consider increasing the amount of UTC funding that is dedicated specifically to AV systems and workforce development targeting displaced workers, such as the drivers mentioned above. Other federal programs, such as the Professional Capacity Building program, may also provide avenues for retraining the workforce to minimize disruption to the job markets.

Senator BARRASSO. Well, thanks so much for your testimony. It will be interesting about this next generation work force. I look forward to getting into that with the questioning.

Commissioner Trottenberg, thank you very much for joining us. Please proceed.

STATEMENT OF POLLY TROTTENBERG, COMMISSIONER, NEW YORK CITY DEPARTMENT OF TRANSPORTATION

Ms. TROTTENBERG. Thank you.

Good morning, Chairman Barrasso and members of the Committee. On behalf of Mayor Bill de Blasio, I thank you for inviting me here today to share New York City's perspective on the deployment of highly automated vehicles in major urban areas.

New York, like our sister cities, shares a common interest in ensuring HAV technology is deployed in a way that enhances urban mobility, safety, and environmental sustainability. We are grateful to have this opportunity to discuss areas of concern and see where there are areas of partnership.

As the Nation's largest and densest city, with a population of 8.6 million and growing, New York City is responsible for the operation and maintenance of a highly complex surface transportation network, including 6,000 miles of heavily traveled urban roadways, 12,000 miles of sidewalks, over 13,000 signals, and nearly 800 bridges and tunnels, many of them well over 100 years old; and we work closely to operate an integrated and efficient transportation system with the MTA, which runs our subway and bus system with over 8 million transit trips per day.

I hope my perspective as a city DOT commissioner and former undersecretary at USDOT will prove useful as the Senate deliberates on the opportunities and challenges we face with HAVs and the implication of this technology for our roads and bridges.

Comments from industry suggest that cities need to get their infrastructure ready for the deployment of HAVs. I would argue just the opposite.

New HAV technology should, instead, be prepared to operate safely and effectively in complex urban environments; in snow, with traffic control officers managing an intersection when signals are out and judgment is needed or where pavement conditions or lane markings are deteriorated. It is simply not realistic or feasible to expect cities to overhaul their existing roadway infrastructure to accommodate a still somewhat unproven technology.

New York is proud to be the first U.S. city to embrace the concept of Vision Zero, which declares that all traffic deaths and serious injuries are preventable. In the last 4 years New York City has achieved remarkable results. Traffic deaths have declined by 27 percent, and pedestrian fatalities have declined by 44 percent. And New York City is bucking the national trend, where, tragically, roadway fatalities have increased by 15 percent.

We have achieved these results through a strong partnership between New York City DOT and the NYPD, as well as robust investment in a comprehensive data driven roadway safety program relying on engineering, education, and enforcement. HAVs hold the promise of dramatically reducing traffic deaths and serious inju-

ries, but to achieve this promise, the U.S. should first establish rigorous foundational safety standards across the board.

For example, the European Commission recently proposed that, starting in 2020, all new vehicles sold in Europe must be equipped with intelligent speed assistance, pedestrian and cycling recognition systems, and automated braking.

In the U.S., we should be advancing similar standards and NHTSA should build on and integrate the best elements of the approaches being used by California and Boston, adopting an approach of incremental testing for HAVs with data sharing requirements.

Cities are where the bulk of Americans live and travel now, and for many, including New York, congestion has become a critical challenge. HAVs hold the promise of reducing congestion or profoundly exacerbating it. Unfortunately, to date, the Federal Government has not meaningfully involved cities in its development of HAV policy. Moving forward, we request that USDOT and NHTSA engage with cities more directly. We will all be most successful as partners, cities, States, USDOT, and the industry.

It is critical to establish protocols that allow HAV safety data to be shared with States and cities. Some data, when appropriate, should also be shared publicly. Providing for a robust level of transparency for HAV safety data will be essential to create a safety culture akin to that of the U.S. aviation sector.

Throughout U.S. history traffic safety has always been a shared responsibility of the Federal, State, and local governments. This authority must be unambiguously preserved in the AV START Act, and HAVs must be programmed to follow all State and local laws, including speed limits.

The legislation also does not require standards based verifiable testing of HAV systems. We urge the Senate to revise the legislation before it advances.

Of all the disruptive challenges HAVs are poised to bring, none may be as consequential as the impact on our Nation's work force. According to recent census data, more than 4.4 million Americans, including approximately 250,000 New Yorkers, make their living driving.

All of our communities, urban and rural alike, will need to confront the potential human toll that this disruptive technology could take. The Federal Government needs to help ensure that innovation and opportunity for some does not mean we are leaving others without a livelihood.

As Congress considers its approach to fast developing HAV technology, I urge you to enlist cities as partners. New York City stands ready to work with you.

I thank the Committee and look forward to your questions.

[The prepared statement of Ms. Trottenberg follows:]

Polly Trottenberg
Commissioner
New York City Department of Transportation

Polly Trottenberg was appointed Commissioner of New York City Department of Transportation in 2014 by Mayor Bill de Blasio. As one of the nation's largest and most diverse municipal transportation agencies, Trottenberg leads over 5,000 employees and a $14.5 billion 10-year capital plan for the City.

After graduating from Barnard College, Trottenberg received her Master's in Public Policy from the Kennedy School of Government. She has over 24 years of experience in the public sector and most recently served as the Under Secretary of Transportation for Policy at USDOT. While there Trottenberg developed key initiatives for the Obama Administration, most notably, the TIGER discretionary grant program. Previously, she became the first Executive Director of Building America's Future, a non-profit organization that advocates for increased investment in infrastructure and major transportation policy reform. On Capitol Hill for 12 years, Trottenberg worked for U.S. Senators Charles Schumer, Daniel Patrick Moynihan and Barbara Boxer before beginning her transportation career at the Port Authority of New York and New Jersey.

As Commissioner, Trottenberg oversees New York City's roads, bridges, traffic and lighting operations, parking, bicycle and pedestrian infrastructure, and passenger ferry service. She has helped lead New York City's Vision Zero traffic safety initiative to reduce roadway fatalities and injuries, with a focus on redesigning hundreds of city streets. Additionally, Trottenberg has worked to prioritize the expansion of street resurfacing and reconstruction, bridge rehabilitation and construction, improvement of bus system performance on city streets, and plans to build a cycling network of over 1,000 miles, doubling the country's largest bike share program.

Commissioner Trottenberg also serves among the City's representatives on the Board of the Metropolitan Transportation Authority. In 2015, she was named Chair of TRANSCOM, a coalition of 16 transportation and public safety agencies in the greater New York Metropolitan area coordinating regional transportation management, data analysis and technology.

TESTIMONY OF POLLY TROTTENBERG
COMMISSIONER, NEW YORK CITY DEPARTMENT OF TRANSPORTATION
SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
"INNOVATION AND AMERICA'S INFRASTRUCTURE:
EXAMINING THE EFFECTS OF EMERGING AUTONOMOUS TECHNOLOGIES ON AMERICA'S ROADS AND BRIDGES"
JUNE 13, 2018

Good morning Chairman Barrasso, Ranking Member Carper, Senator Gillibrand and Members of the Committee. On behalf of Mayor Bill de Blasio, I thank you for inviting me here today to share New York City's perspective on the policy and infrastructure questions surrounding the deployment of highly automated vehicles (HAVs) and other emerging automotive technologies in major urban areas.

As the nation's largest and densest city, with a population of 8.6 million and growing, New York City is responsible for the operation and maintenance of a highly complex surface transportation network, including 6,000 miles of heavily traveled urban roadways, 12,000 miles of sidewalks, over 13,000 signals, and nearly 800 bridges and tunnels, many of them well over 100 years old, including the iconic Brooklyn Bridge. I hope my perspective as a city DOT Commissioner will prove useful as the Senate deliberates on the opportunities and challenges we face with HAVs. I also previously served as Under Secretary for Policy at USDOT.

In many ways, New York City stands alone in its size and complexity, with an annual budget of $3.5 billion and nearly 5,500 employees, and our City DOT is larger than many State DOTs. But we have found that major U.S. cities share a common interest in ensuring HAV technology is deployed in a way that dramatically enhances urban mobility, safety, and environmental sustainability. As an active member of the National Association of City Transportation Officials (NACTO), our perspective on HAV technology is guided by both our own experience as well as an ongoing dialogue with our peers.

Few innovations have shaped American society and our modern landscape as much as the automobile, which has provided Americans with unprecedented mobility and economic opportunity. New HAV technologies have the potential to bring further dramatic change to the U.S. transportation system. But the automobile has brought significant challenges, including congestion, sprawl, too many roadway deaths and negative environmental impacts. In many ways, urban areas feel these challenges most acutely. If we do not proceed carefully, HAV technology could instead exacerbate many of these problems and could potentially create new unintended consequences.

While my testimony today focuses on the challenges cities face, I do want to note that of course rural communities will also have their own, potentially quite different, concerns and priorities as HAVs are studied and tested further.

Urban Environment

New York City, with its thriving economy, continues to attract more visitors, workers, and residents than ever before. Since 1990, we have added 1.2 million people to our population — nearly the size of Dallas. Last year we saw 62 million tourist visits alone, and we are also experiencing a citywide construction boom, the growing use of for-hire vehicles, and home delivery services adding more freight to our roadways than ever before. Our subways, streets, and sidewalks are overflowing, and NYC DOT is challenged with trying to make all these moving components operate safely and harmoniously in cooperation with the MTA, which runs our subway and bus system with over 8 million trips per day. It is a big job which never ends.

Comments about HAVs from automakers and industry personnel continue to suggest that cities and other localities need to "get ready" for the deployment of HAVs and that we need to rethink

our approach to roadway design and infrastructure maintenance. I would argue just the opposite. New HAV technology should instead be prepared to operate safely and effectively in complex urban environments, on streets with pedestrians overflowing into parking lanes, construction workers waving instructions to redirect vehicles, time-of-day restrictions on bus lanes, and sometimes deteriorated pavement conditions and lane markings.

The promise of an HAV is that it can be "more aware" and less distracted than a human driver. These vehicles then should be able to drive in all the conditions human drivers can: in snow, with traffic control officers managing an intersection, or in situations where a signal is out and judgment and discretion are needed.

Moreover, with an enormous backlog of critical infrastructure needs nationwide and insufficient federal, state and local dollars to pay for it, governments must prioritize the investment of scarce dollars. It is not realistic or feasible to expect cities and states to overhaul their existing roadway infrastructure to accommodate a still somewhat unproven new technology. This would potentially add an unsustainable financial burden to the hundreds of millions of dollars we currently spend annually on maintenance and rehabilitation of our heavily used roadway network.

Safety

New York City is working aggressively to improve our streets to increase safety. We are proud to be the first U.S. city to embrace the concept of Vision Zero, which declares that all traffic deaths and serious injuries are preventable. In the four years following the adoption of Vision Zero, our results have been encouraging. Traffic deaths in New York City have declined by 27 percent and pedestrian fatalities have decreased by 44 percent. We have achieved these results through a strong partnership between NYCDOT and the NYPD, as well as a robust investment in a comprehensive,

data-driven roadway safety program relying on engineering, education and enforcement. And New York City stands in contrast to the national trend, where tragically roadway fatalities have increased by 15 percent over the last four years.

If developed and implemented with a rigorous safety process, HAVs hold the promise of dramatically reducing traffic deaths and serious injuries nationwide. But to achieve this promise, the U.S. should establish rigorous foundational HAV safety standards across the board as we are seeing other countries do.

For example, the European Commission (EC) recently proposed that, starting in 2020, all new vehicles sold in Europe must be equipped with Intelligent Speed Assistance pedestrian and cyclist recognition systems, and automated braking, which are all core elements of HAV technology. According to studies for the EC, utilizing Intelligent Speed Assistance in Europe could prevent 30 percent of auto collisions and 20 percent of road deaths, while cutting motor vehicle emissions by 8 percent.

In the U.S., we should be advancing similar safety standards for motor vehicles and the National Highway Traffic Safety Administration (NHTSA) should build on and integrate the best elements of the approaches being used by the State of California and the City of Boston, adopting an approach of incremental testing for HAVs with data sharing requirements. Certified testing in controlled environments, paired with a gradual ramp up for larger metropolitan areas, would be more responsible than the current proposed deployment strategy.

Congestion

We also need to ensure that HAVs reduce, rather than increase urban congestion, which is costing the New York metro area approximately $20 billion annually in lost economic productivity

and poorer quality of life. Congestion in New York City is at record levels and we have seen in recent years that the app-based For-Hire-Vehicle (FHV) sector has been a significant driver of this growth. In the core of Manhattan alone, combined trips by yellow taxis and app-based FHVs have increased by 17 percent between 2013 and 2017 and travel speeds have dropped significantly.

And recently, New York City has started to see a decline in annual subway ridership for the first time in almost a decade. Our travel data and that from other major cities suggests that a portion of FHV trips are by users who would have previously taken mass transit. New York City and other cities depend on a wide range of modes for their transportation networks to function each day and reduce congestion and gridlock.

If not implemented carefully, HAV technology has the potential to congest our streets and worsen our air quality even more dramatically. But if implemented appropriately, HAVs could bolster more efficient ridesharing services and potentially lead to a reduced demand for personal vehicle ownership in transit rich cities like New York.

Over time, cities will need to study appropriate regulations to mitigate the congestion impacts of this growth, and we will need continued support from states and Congress to improve and encourage the use of public transit and other sustainable modes of travel. If HAV technology just results in thousands more single-occupancy, or even zero-occupancy vehicles flooding our city streets, it would be a major setback for mobility and quality of life in urban communities. A key way we can do this is with data. Data sharing can help us better assess and manage the negative congestion impacts we are currently facing within our City. Whether it's a particularly troublesome intersection or an routinely congested street, data, as I will address further, can help us resolve these issues and keep New Yorkers moving.

The Role of the Federal Government

Because there are such profound implications for our infrastructure and the safety of our residents, cities must have a seat at the table and the opportunity to provide input on HAVs to policymakers and regulators. Unfortunately, the Federal government has not meaningfully involved cities to date. NHTSA recently revised its voluntary guidance on HAVs to States and other stakeholders. This revised framework contains few references to city transportation officials, leaving them out of critical recommendations such as involvement in State Commissions. Just as cities and local officials must be included in the Advisory Committees that would be established in the AV START Act, the Federal government should clearly articulate the importance of local government engagement in any guidance to State officials. We are also concerned that this guidance does not include mandatory manufacturer safety assessments.

Moving forward, we continue to request that USDOT and NHTSA engage with cities more directly, and create more opportunities to share best practices across all levels of government. The bulk of the U.S. population lives and travels in urban areas and local transportation officials have deep expertise, particularly in on-the-ground infrastructure operations and maintenance. We should be included in this process formally on an ongoing basis.

Partnerships

As I noted, we will all be most successful if we can partner: cities, states, USDOT, and manufacturers, in order to develop meaningful solutions now for the eventual testing and deployment of HAVs and address future infrastructure needs. The Federal government is already doing this in some instances and should continue and expand its efforts.

The National Science Foundation is investing in research partnerships involving government, industry and academia on next generation internet technology — and New York City is home to one such 5G research testbed. Similarly, USDOT launched a program to test the deployment of Connected Vehicle (CV) technology. These vehicles are not HAVs, but can use technology to communicate with other vehicles and infrastructure to prevent crashes and increase roadway throughput.

Through a USDOT grant, New York City was selected to conduct a five-year CV tech deployment pilot along Manhattan's FDR Drive as well as in up to 400 locations in midtown Manhattan and Brooklyn. These intersections are being equipped with devices that will communicate with approximately 7,000 vehicles enrolled in the pilot. The pilot also connects with our existing network of smart traffic signals that communicate wirelessly with our Traffic Management Center. We will start full operations in 2019, and hope to move to citywide implementation with the lessons learned from this pilot. We feel strongly that HAVs need to incorporate CV technology in order to eventually operate safely and efficiently on city streets.

Data Sharing

It is also critical to establish protocols that allow HAV safety data to be shared with states and cities. Some data, when appropriate, should also be shared publicly. While we recognize that testing data is precious to each company and some may pertain to intellectual property, providing for a robust level of transparency and disclosure of safety and other performance data will be essential for establishing public confidence and in creating a safety culture akin to what we have developed in the U.S. aviation sector.

Currently there are no regulatory mandates requiring or even encouraging HAV data sharing, and some manufacturers have been unwilling to enter data sharing agreements with cities. This lack of regulatory mandates and industry participation concerning data sharing leaves cities unable to evaluate the results of HAV deployment, and externalities like congestion, for example. And it leaves us unsure that the technology is ready for the unique challenges of dense urban areas, especially in light of the tragic and disturbing pedestrian fatality that occurred during testing in Tempe, Arizona.

Although the AV START Act mandates the creation of an HAV Data Access Advisory Committee to make policy recommendations to Congress concerning data sharing, the Committee must be formed within 180 days after the enactment of the Act and has two years to make policy recommendations to Congress which may or may not be accepted and codified into law. In the interim years, cities may have no access to this critical data as HAVs are being tested on city streets.

The wealth of crash, travel demand, and traffic congestion data that HAVs will collect have the potential to inform municipal transportation agencies' on how they can better design safer and more efficient streets. For example, operational data has proven invaluable to New York City in shaping our understanding of the congestion challenges associated with the increased usage of FHVs. Data sharing will help us to address our congestion concerns, and it will help us to better understand and implement the most appropriate policies that seek to help our City with its unique infrastructure needs.

AV START Act

In addition to the lack of data sharing requirements within the AV START Act, many cities have other concerns regarding this legislation. While it is intended to speed the deployment of HAVs and streamline requirements, the current version of the AV START Act that was reported out of the Senate Committee on Commerce, Science and Transportation has the potential to cause confusion concerning the ability of state and local authorities to adopt and enforce traffic laws regulating the use and operation of HAVs.

Throughout U.S. history, traffic safety has always been a shared responsibility of the Federal, state and local governments. Having worked at both the Federal and local level, I know that NYC DOT's engineers and planners, working with our law enforcement partners in the NYPD, are best equipped to make local regulatory and enforcement decisions. In order to further reduce traffic fatalities, this authority must be unambiguously preserved, and HAVs must be programmed to follow all state and local traffic laws, including speed limits. Our experience with Vision Zero is that in the urban context, the biggest driver of roadway safety and saving lives is speed control, and HAVs must be integrated into our ongoing Vision Zero work.

Additionally, the legislation dramatically increases the number of HAVs that each company can sell or operate on public roadways that do not comply with Federal Motor Vehicle Safety Standards, but does not require that NHTSA develop specific safety standards for HAVs on any mandated timeframe. The legislation has some useful provisions regarding cyber security and makes safety evaluation reports (SERs) mandatory. However, the SERs are only created and self-certified by manufacturers for completeness and accuracy, with no opportunity for independent assessments and no enforcement mechanisms. We recommend the Senate revise and strengthen those provisions before enactment to require standards-based, verifiable testing of HAV systems.

Workforce

I know creating economic opportunity for working Americans is a common goal all the members of this Committee share. Of all the disruptive changes HAVs are poised to bring, none may be as consequential as the impact on our nation's workforce. According to recent Census data, there are more than 4.4 million Americans who make their living driving taxis, buses, vans, trucks and for hire vehicles. In New York City alone, we estimate that there are approximately 250,000 drivers whose jobs could be displaced by HAV technology.

Nationwide, many of these workers lack a college degree and are therefore potentially very vulnerable to major industry disruptions. As we consider all the safety and mobility implications of HAVs, all of our communities, urban and rural alike, will need to confront the potential human toll that this disruptive technology could take. The Federal government needs to lead here as well and help insure that innovation and opportunity for some does not mean we are leaving others without a livelihood.

Conclusion

As Congress considers its approach to fast-developing HAV technology, I urge you to enlist cities as partners. We all have an interest in reducing congestion, curbing traffic fatalities, improving air quality and protecting workers. We think U.S. cities can bring a lot of valuable expertise to the table and New York City stands ready to work with you. Thank you for your time this morning and I look forward to your questions.

NEW YORK CITY Department of Transportation
POLLY TROTTENBERG, Commissioner

June 27, 2018

Honorable John Barrasso
Chairman, Senate Committee on Environment
and Public Works
410 Dirksen Senate Office Building
Washington, DC 20510

Honorable Tom Carper
Ranking Member, Senate Committee
on Environment and Public Works
456 Dirksen Senate Office Building
Washington, DC 20510

Dear Chairman Barrasso and Ranking Member Carper,

Thank you for inviting me to testify before the Senate EPW Committee to discuss highly automated vehicles (HAVs) and the impacts we believe they will have on urban transportation infrastructure. I enjoyed participating in the robust discussion that addressed the need for NHTSA to establish nationwide safety standards for HAVs. As follow up, I wanted to further emphasize the significant workforce implications of HAV deployment. Additionally, I would like to share the newly-adopted resolution by the United States Conference of Mayors (USCM) hearing regarding autonomous vehicles, and New York City's response to the EPA's final rule on fuel economy standards.

Workforce

Across the country, professional driving positions, spanning the trucking, taxi, black car, van, and bus sectors, are among the shrinking number of well-paying jobs that generally do not require a college degree. As I testified, Congress and the federal government will need to play a central role in helping these workers adapt to the changing labor market.

The experience of professional drivers in New York City illustrates the need for bold federal action. Our Taxi and Limousine Commission (TLC), which regulates taxis and for-hire vehicles (FHVs), including app-based providers like Uber and Lyft, licenses approximately 185,000 drivers operating over 126,000 vehicles. Squeezed by the downward pressure on wages resulting from Uber and Lyft's competition with the taxi industry and each other, these drivers are finding it increasingly difficult to make a living and support their families. To try to reverse this trend, New York City is taking steps to protect driver income by ensuring they have money left over after covering their baseline operational expenses. While the situation seems dire now, with vehicle automation on the horizon, this problem could get dramatically worse. We urge Congress to take the threat of job loss seriously, and begin preparing now, across committees and federal agencies and in collaboration with state and local partners, to help protect workers' wages and create pathways to new employment for those that will be displaced by HAVs.

Emissions

As I mentioned during the hearing, New York's public transit system will always be the workhorse of our transportation network. However, like many other US cities, as our population grows and app-based FHV services attract more and more users, our street network is straining to keep up

with demand. Traffic in the Manhattan Central Business District is worse than it has ever been; the average travel speed in Midtown is down to five miles per hour. Congestion costs the New York metro area approximately $20 billion annually. And, after several years of falling bus ridership, we are starting to see subway ridership decline, too.

As with the workforce concerns, without meaningful preparation and appropriate regulatory steps, these developments could worsen with the deployment of HAVs. If, as a result of automation, the cost of FHV service drops enough to become competitive with transit, or commuters choose to ride into cities every day from far-flung exurbs, urban congestion and greenhouse gas emissions (GHG) could grow significantly. New York City is committed to reducing GHG emissions by at least 80 percent by 2050 (80 x 50), joining the world's leading cities in doing our part to reduce our contributions to catastrophic climate change. Achieving this goal requires significant reductions in emissions produced, in part, by the city's transportation. We now know that to achieve 80 x 50 the City must accelerate efforts to increase our energy efficiency, which includes reducing the number of miles driven in the City while replacing remaining vehicles to zero-emissions vehicles. I hope the Committee will explore ways in which Congress could avoid or mitigate these trends by strengthening urban transit systems, strengthening fuel economy standards and encouraging electrification in the HAV market, and deploying pricing and regulatory tools to keep demand for single occupancy vehicles in check.

Relatedly, the EPA recently published a final rule that curtails future improvements in fuel economy standards, and will soon propose a rule setting significantly weaker standards and preventing states from promulgating separate and stricter emission standards. NYC will file an amicus brief in support of California's recent petition in federal court seeking the review of EPA's withdrawal of future fuel economy standards. Because HAVs could dramatically increase vehicle miles traveled, I would urge the Committee to review their potential environmental impacts before streamlining the deployment of these vehicles.

USCM HAV Resolution

As the Committee continues to review this critical issue, I would also like to share a copy of the attached AV Resolution recently adopted by USCM. The resolution calls for improvements to S.1885 the "AV START Act," by urging Congress to adopt safe and reliable policies when testing and deploying HAVs on our roads and highways. The resolution further calls on Congress to include a provision confirming localities' authority to regulate HAVs' compliance with traffic laws. Finally, the resolution calls for data sharing with localities and for the issuance of federal safety standards concerning HAVs within the next eight years.

Thank you again for inviting me to testify on behalf of the City of New York. I appreciated the opportunity to share New York City's perspective on HAVs, and consider them in the context of Vision Zero, our groundbreaking initiative to eliminate traffic fatalities. We hope that Congress will take the steps necessary to make sure that HAV deployment supports the success we have seen to date in making our streets safer, and address the significant and pressing workforce and emissions challenges that this potentially transformative technology presents.

We are ready to work with your staff to help address these concerns as Congress seeks to implement policies that encourage the safe testing and deployment of HAVs on our nation's roads and highways.

Sincerely,

Polly Trottenberg
Commissioner

PT:jb:rc

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NEW YORK CITY Department of Transportation
POLLY TROTTENBERG, Commissioner

Senate Committee on Environment and Public Works
Hearing entitled, *"Innovation and America's Infrastructure: Examining the Effects of Emerging Autonomous Technologies on America's Roads and Bridges."*
June 13, 2018
Questions for the Record for Commissioner Polly Trottenberg

Ranking Member Carper:

1. Early, high-profile crashes of autonomous vehicles have sowed public concerns and potentially distrust of autonomous vehicle technology. What improvements to the infrastructure necessary to support autonomous vehicle technology must occur in order to ensure that deployment of AVs builds public confidence? Specifically, what steps can the EPW Committee take to ensure that infrastructure helps to support the safe operation of these vehicles?

   Automakers and other AV developers regularly cite roadway condition as an important factor in AV performance. As I indicated in my testimony, New York City does not accept the framing that suggests cities and other localities need to "get ready" for HAV deployment. While additional federal funding for state-of-good-repair work is critical, new HAV technology should be prepared to operate in complex urban environments, including on roadways that may have deteriorated pavement or lane markings. It appears that recent crashes, such as the pedestrian fatality in Arizona, was a result of lax deployment processes, rather than the conditions of the roadway infrastructure on which they were operating.

To ensure AVs can drive safely on public streets, Congress and USDOT must take a more active

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role in creating safety standards and testing protocols for AVs, as well as requiring transparency in testing procedures. The US should also follow the European Union's lead on requiring proven safety features in all new vehicles, including intelligent speed assistance, automatic emergency braking, as well as pedestrian and cyclist recognition. These technologies are ready now and could have profound safety impacts long before fully-automated vehicles are widely available.

Large urban centers like New York City rely heavily on public transportation first and foremost. We remain concerned that AVs, if not properly regulated could exacerbate congestion, which is costing the New York metro area approximately $20 billion annually in lost economic activity. The EPW Committee can be a partner with cities in their advocacy for increased federal support for public transportation and other sustainable modes of travel. The Committee can also insist that the federal government enlist cities as partners so that widespread AV displacement does not result in increased urban congestion and worsened air quality.

2. Given that the House and Senate AV bills provide NHTSA with new exemption authority to permit thousands of AVs on the roads while also preempting states from regulating AVs, are there minimum infrastructure conditions, design changes, or Vehicle-to-Infrastructure connectivity policies that need to be established at the national level? Should these changes be implemented before widespread deployment occurs?

We agree that, as written, the AV START Act could lead to the preemption of states and cities from regulating AV compliance with local traffic laws. That would result in a real safety risk and is unacceptable.

Federal standards for connected vehicle (CV) technology, such as the pending USDOT rulemaking to require all new vehicles be equipped with vehicle-to-vehicle communication equipment, would create a more supportive environment for safe AV operation and, therefore, help speed CV deployment. As Wyoming DOT Director Panos noted in his testimony, infrastructure owner-operators cannot justify public investment in connected infrastructure until we know whether it is

compatible with a majority of new vehicles. CV standards should be established prior to the widespread deployment of AVs.

Comments about AVs from automakers and industry personnel continue to suggest that cities and other localities need to "get ready" for the deployment of HAVs and that we need to rethink our approach to roadway design and infrastructure maintenance. We reject this premise and the unfunded mandate it presents to local communities throughout the country.

3. In aviation and surface transportation settings, pilots and drivers must be certified to operate vehicles through a licensing process. Given the variation in how AV technologies operate and detect the roadside environment through probabilistic reasoning, should there be a similar licensing approach to certify that AVs are adequately prepared to detect the roadway signs, markings, infrastructural elements, and other users of the road? If yes, how so? If no, how might we otherwise ensure that in complex urban environments, for example, that highly autonomous vehicle technology is prepared to operate safely and effectively?

We strongly agree that USDOT should develop a baseline assessment of an AV's ability to recognize other road users and infrastructure before allowing them on public roads. One option for these tests would be to expose the vehicle's vision systems to a large body of images and video from a range of street environments and conditions. This would allow regulators to determine whether the system's ability can perform the following functions: properly identify pedestrians, cyclists and other motorists: predict behavior: and recognize markings and traffic control devices. While a vision test would not guarantee readiness for on-road operation, it would eliminate unfit systems and, therefore, increase public confidence in the safety of AVs operating on public streets.

4. A significant number of roadway fatalities in this country occur on rural roads. One of the biggest challenges regarding the use of connected and automated vehicles is the lack of

required infrastructure features to accommodate them in rural parts of the country. What can and should we be doing to prepare rural America for the expanded use of AVs?

As a dense urban city, we have very different challenges from our rural counterparts. We defer to their expertise on this question.

5. Truck platooning could be one of the earliest forms of automation technology to be broadly adopted on our nation's roadways. This technology allows trucks to run close to one another in a caravan formation. From an infrastructure perspective, this creates the potential for trucks to use roads more efficiently. On the other hand, bridges have been designed for greater spacing between heavy trucks, therefore more needs to be learned on whether bridge spans can safely handle the added dynamic weight. What research has been done into the impact that platooning could have on the structural integrity of our bridges? How many platooned trucks do you think most bridges could reasonably hold? Do you think there should be a limit to the number of vehicles allowed in a platoon in order to avoid this damage to our nation's infrastructure?

NYC DOT maintains 789 bridges across the five boroughs, 684 of which carry vehicular traffic. Many of our bridges are quite old and, therefore, we are uncertain as to whether they would be able to accommodate truck platooning, particularly with the overweight vehicles that are often used. The increased volume of vehicles also has significant air quality implications. This topic warrants significantly more research prior to its introduction.

6. What should transportation planners begin doing now to accommodate AVs? How long will such planning and implementation require?

Cities will need to re-double our current efforts to incentivize sustainable modes of transportation, including transit, cycling, and walking, to ensure that they remain competitive with AVs. This

requires improvements to transit service and accessibility; increased infrastructure for cycling, and safer and more accessible intersections for pedestrians, as well as the expansion of public space amenities, such as pedestrian plazas and wider, more amenable sidewalks. Without these measures, AVs will likely attract travelers who choose sustainable modes, which will ultimately lead to dramatically worsened congestion, less equitable transit service, and a diminished quality of life for our residents.

New York City is developing a New Mobility Roadmap, which will identify goals and potential actions for the city to pursue to encourage electrification, as well as maximize the benefits of shared mobility services and automation while at the same time mitigate any potential risks. These documents will also link new mobility services to our existing municipal goals and operations and better contextualize them within our vibrant and complex transportation system. We see this activity as a necessary first step in preparing our streets and agencies for AVs and other emerging transportation technologies and services.

Cities need safety and performance data, during both testing and deployment to better understand how AVs operate on our streets. Coalitions like Transportation for America's Smart Cities Collaborative are working across cities to develop a common set of data-sharing standards that will identify municipal needs in the most effective and least burdensome format. This data is crucial for cities to verify the claims of the private sector, as well as assess the safety, equity, and congestion impacts of these technologies.

Federal leadership in requiring data-sharing among states and municipalities would be an enormous boon to effective planning. AVs will collect an enormous amount of invaluable crash, travel demand, and traffic congestion data that could be used by municipal transportation agencies to design safer and more efficient streets. For example, operational data has proven invaluable to New York City in shaping our understanding of the congestion challenges associated with the increased usage of FHVs. Data sharing will help us to address our congestion concerns, and it will help us to better

understand and implement the most appropriate policies that seek to help our City with its unique infrastructure needs.

7. In Japan, the Japanese government is leading testing of AVs, which is currently restricted to major limited access highways rather than on urban streets. In testimony for this hearing, we also heard from both the Wyoming Department of Transportation and New York City Department of Transportation about their implementation of a USDOT pilot program that explores connected vehicle application concepts within limited, specific pilot sites for a finite duration. This allows the agencies to assess the impacts and evaluate the benefits. What are the pros and cons of taking what could be considered a more limited approach?

We strongly support this approach and believe that local transportation agencies should be lead partners in any AV testing on their streets. Boston's program for AV testing is a great example. This model is safer, helps resist the market pressure to put under-prepared vehicles on public streets, and fosters greater transparency and accountability in the testing process. It also improves the information exchange between companies and the public sector. Finally, it gives the City more leverage to encourage companies to address accessibility and equity in service, which are two major potential benefits that both the AV industry and current ride-hailing companies have been slow to address.

Senator Whitehouse:

8. As our vehicles move towards automation, this change will require that our infrastructure and roadways are updated to ensure that autonomous vehicles operate safely and efficiently. Upgrades could include well-marked lanes, accurate signage, and traffic lights that can communicate easily and clearly with autonomous vehicles.
    a. What type of upgrades and investment should we be making now to our existing roadways and infrastructure to accommodate autonomous vehicles?

b. Should we be making changes to our infrastructure and roadways with the intention that the vast majority of vehicles in the future will be autonomous?
c. If electric vehicles make up the fast majority of autonomous vehicles, what type of infrastructure changes will we need to facilitate this transition?

Our Vision Zero program has been a great success in reducing traffic fatalities and serious injuries as a result of crucial Safety Improvement Projects (SIP) that have been implemented at key intersections and corridors with the highest crash data. These projects re-engineer intersections and corridors to improve safety for road users (pedestrians, cyclists and motorists) by implementing a range of traffic calming measures, including: increasing space for pedestrians and cyclists; narrowing travel lanes to reduce speeding; removing dangerous turn conflicts: and simplifying complex intersections so they are easier to navigate. In addition, we have installed Leading Pedestrian Intervals (LPI) throughout the city, which by dedicates 7 to 10 seconds at the start of the signal phase to allow pedestrians to cross before parallel traffic starts, thereby reducing conflicts with motorists. We have also improved our crosswalk and street markings to increase visibility and safety for pedestrians and motorists.

These steps are not only critical for improving traffic safety right now, but will also improve the environment for AVs in the future by making it easier for them to navigate.. They also simplify the system and protect vulnerable road users by eliminating vehicle-pedestrian/cyclist and vehicle-vehicle conflicts before they happen. We must continue to prioritize these types of improvements and we urge Congress to increase funding to support them.

With federal funding and equipment requirements, CV infrastructure could supplement AV performance to enhance safety and efficiency. As with Vision Zero street redesigns, dedicated short-range communication (DSRC) technology can be implemented now, therefore saving lives before the introduction of AVs, as well as enhancing AV operation once they arrive.

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Finally, to spur electric vehicle adoption, cities and utilities will need to invest significantly in charging infrastructure. The City of New York is committed to dramatically increasing the number of electric vehicles (EVs) on its streets as part of the City's plan to reduce greenhouse gas emissions 80% by 2050. The City is currently electrifying its own light-duty vehicle fleet, with the goal of creating the largest electric fleet of any U.S. city. In addition, the City has set a goal that 20% of all new vehicle registrations will be electric by 2025. To support that goal, the City plans to install 120 level 2 EV chargers at curbside locations in partnership with Con Edison (the local utility) and is creating a network of up to 50 fast charging stations across the five boroughs. In dense urban areas where residential charging is difficult, this means both on-street Level 2 charging, with a lower power draw and multi-hour charge time, and fast-charging stations which offer a gas-station experience at greater cost.

Additional federal support for charging infrastructure would accelerate adoption and increase the feasibility of fully-electric urban fleets. To support the increase in electricity demand, cities and utilities will also require help in upgrading power grids. And, at the vehicle level, aggressive fuel economy standards and federal incentives for purchasing EVs would increase uptake and prompt utilities to deploy more charging infrastructure.

9. Transportation is now the largest source of carbon emissions in the United States, and carbon emissions from cars and light trucks account for almost one-sixth of the nation's total emissions. We should be implementing policies in this sector with an eye towards reducing our emissions.
    a. How can we design the right policies so that autonomous vehicles that enter our roadways are fuel-efficient and help us reduce our transportation emissions?
    b. Do we know how autonomous vehicle adoption will affect overall traffic patterns and the number of miles driven by cars? If not, what is the best way to study and better understand this?

Facilitating electrification in the AV fleet may be one of our best opportunities to drive down national greenhouse gas emissions in our transportation sector. As noted previously, this will require a concerted effort and investment from municipalities and utilities to deploy different types of charging infrastructure at locations that are accessible and convenient for urban motorists, fleet operators, and, in the future, AVs. While New York City and Consolidated Edison (the city's primary electricity provider) are now deploying charging infrastructure to encourage electric vehicle adoption, we do not yet knowhow today's charging infrastructure will interact with tomorrow's driverless vehicles. With that said, we hope to see more research on this topic.

Beyond electrification, cities will need tools to encourage AVs to operate efficiently on city streets. In areas with robust public transit systems, AVs must supplement, rather than replace existing transit service and connect more people to high-capacity modes which move people most effectively and equitably throughout dense urban centers. Without policies that encourage shared rides and transit use, the number of vehicle miles traveled (VMT) is likely to skyrocket, even if fewer vehicles may be needed to accomplish the same number of trips.

Boston, in partnership with the World Economic Forum and Boston Consulting Group, found that even in conservative use estimates, AVs will worsen congestion and increase VMT in urban cores by pulling riders from public transit. Federal support for additional modeling studies similar to the one conducted for Boston would be very helpful in identifying the range of possible impacts of AVs to each region and metropolitan area.

As the European Union recently proposed, another step that could be taken now to support greater fuel and energy efficiency of motor vehicles and automated vehicles is to require Intelligent Speed Assistance (ISA) technology to start with model year 2020 vehicles.. This technology is a core element of vehicle automation that does not require deployment of full automation to deliver massive societal and mobility benefits. The European Union estimates that mandating ISA will reduce traffic crashes by 30 percent and fatalities by 20 percent, as well as cut greenhouse gas pollution and related

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fuel use by 8 percent. By adopting ISA as part of motor vehicle safety standards, NHTSA could help U.S. carmakers compete globally in the field of vehicle automation and also bring near-term benefits.

10. Reports suggest that the autonomous vehicle industry could expand into the trucking industry, e-hailing, and ride-sharing industry.
    a. How soon can we expect widespread adoption of autonomous vehicles in these industries?
    b. How can we get ahead of the potential job losses that could occur in traditional trucking and ride-sharing industries if autonomous vehicles are widely adopted?
    c. Do we need to consider job retraining and workforce development policies to ensure that autonomous vehicle deployment does not disrupt the job markets for taxi, bus, and shuttle drivers?

While we cannot accurately forecast AV adoption rates, it seems clear that industry is preparing for AVs to operate in ride-hailing platforms, competing with human drivers, in the very near future. Waymo and GM's Cruise Automation have both announced their intention to launch their own services by 2019. Industry has also begun to take seriously the potential for significant job displacement, with several leading companies forming the Partnership for Transportation Innovation and Opportunity, which is aimed at developing solutions to address the negative employment outcomes of the technology.

It will take years to identify, enact, and implement public policy solutions to help affected drivers, and I urge Congress to begin now. In New York City, we are already seeing the significant financial and emotional harm drivers are experiencing as their wages decrease because of the he explosive growth in the driver population of the app-based for-hire vehicle (FHV) industry. A recent study supported by our Taxi and Limousine Commission found that, after subtracting vehicle expenses, 85% of our FHV drivers now make less than the state's minimum wage ($15 per hour), , while at the same time are trying to pay off vehicles they bought expressly for these services. These problems

could get much worse as AVs begin to compete with human drivers, which could potentially drive down the price of transportation even further.

Workforce retraining will be a necessary component of any suite of solutions to this problem. While industry groups recently formed the Partnership for Transportation Innovation and Opportunity to examine workforce impacts, the federal government needs to lead this discussion and the formulation of appropriate policy responses. As Congress is considering the approach, please keep in mind the differences in the driving populations of different regions. Over 90% of taxi and FHV drivers in New York City are immigrants and have different levels of language proficiency and educational attainment as opposed to the trucking sector. To be successful, retraining programs will need to respond to the specific characteristics of the population they are meant to help.

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Senator BARRASSO. Thank you so much for your testimony, Commissioner Trottenberg.

Mr. Kildare.

STATEMENT OF SHAUN KILDARE, DIRECTOR OF RESEARCH, ADVOCATES FOR HIGHWAY AND AUTO SAFETY

Mr. KILDARE. Good morning, Chairman Barrasso, Ranking Member Carper, and members of the Committee. I am Shaun Kildare, Director of Research for Advocates for Highway and Auto Safety, a coalition of public health, safety, consumer organizations, and property/casualty insurance companies dedicated to advancing safer vehicles, safer drivers, and safer roads. Thank you for the opportunity to testify.

Each year motor vehicle crashes kill tens of thousands of people and injure millions more, at a cost of over $800 billion. Moreover, at a time when deaths on our Nation's roads are remaining unacceptably high, America's infrastructure is in deep disrepair. The American Society of Civil Engineering gives our roads a grade of D and reports that 1 in 11 of our nearly 615,000 bridges are structurally deficient.

In addition to committing resources to fix our roads and bridges, substantial investments will be required to ensure that autonomous vehicles, or AVs, can operate safely. Federal leadership is needed to achieve infrastructure improvements and to create a regulatory framework for vehicle design and performance.

Advocates has always been a strong champion for vehicle safety technology and infrastructure improvements. So, too, do we believe that in the long-term AVs may once and for all bring about meaningful reductions in the death and injury toll on our Nation's roads. The industry touts that AVs will improve safety, reduce congestion, and benefit the environment. Instead, what we have seen is a number of crashes resulting in at least three deaths.

At the time of the fatal pedestrian crash in Arizona, Uber had logged approximately 3 million autonomous miles. While that may sound like a large number, consider that every year Americans drive 3 trillion miles. During those 3 trillion miles, on average, a person was killed in a traffic collision every 85 million miles in 2016. In comparison, Uber's AV fatality rate is 28 times that of human drivers. This highlights just how little proof there is that these systems are safe or certainly not safer than human drivers presently.

Statements regarding reductions in congestion and improvements in the environment are similarly dubious. There is a wide variation regarding estimates of changes in vehicle miles traveled. Often absent from these urban planning utopias is the reality that AVs may bring the possibility of hypercommuters living several hours outside of cities. Also frequently missing is the likelihood of empty vehicles circling aimlessly between rides.

What we do know is that after the March 23rd Tesla crash in California, U.S. Highway 101 was closed for nearly 6 hours. The battery was on fire, emitting dangerous chemicals, and the battery reignited 5 days afterwards. That paints a very grim picture.

The fact is that rushing to deploy AVs provides no guaranty of the benefits claimed and may come with significant costs. Despite

these uncertainties, the USDOT has chosen to take a hands off approach by issuing only voluntary guidelines. Therefore, Advocates has put forth several reasonable proposals which are outlined in my written testimony.

Regarding infrastructure improvements, we offer the following three recommendations:

First, for road design. The lynchpin for much of the guidance in numerous infrastructure manuals is a human behind the world. From sight distances for signs, to lettering, to the curvature and super elevations of roads, infrastructure design criteria has been developed to enable a safe operation of vehicles by human drivers. AVs may require that these basic premises be modified in order to serve a dual purpose for both human and computer driven vehicles.

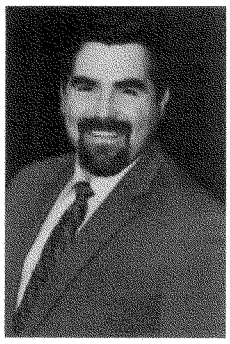
Second, roadway deterioration. We have all experienced road signs or markings that have been damaged intentionally or altered or blocked by objects. Research shows that a stop sign can easily be manipulated with a few pieces of tape, which is then read by the AV to be a 45 mile an hour speed limit sign, resulting in the AV speeding up instead of stopping. This is why Advocates is recommending AVs be subject to a vision test. When a person goes to a DMV to get a license, he or she has to take a vision test. With the AV now being the entity that is seeing the road, AVs should have to demonstrate that they can see and respond to the roadway challenges.

Third, connected vehicles. These technologies allow a vehicle to send and receive communications with other vehicles, known as V2V, or the infrastructure, known as V2I. They will likely help fill gaps in AV performance. For example, V2V communication can provide safety applications for Forward Collision Warnings which alert drivers to stopped or slowed vehicles ahead. Advocates has filed comments in support of mandating V2V; however, the rule continues to languish at USDOT.

To conclude, this hearing is very well timed, considering that last week the NTSB released their preliminary report on the fatal Tesla crash in California this March. It appears likely that infrastructure components may have been a factor in that crash. As such, we urge the Senate to allow time for the NTSB to finish its pending investigations on AV systems. There is a great deal to be learned from our Nation's leading investigators, and there is no reason to rush through legislation, especially by tacking it on to an unrelated bill.

I look forward to your questions.

[The prepared statement of Mr. Kildare follows:]



Shaun Kildare, Ph.D.
Director of Research
Advocates for Highway and Auto Safety

Dr. Kildare is the Director of Research at Advocates for Highway and Auto Safety. He holds a B.S. in Biomedical Engineering from Case Western Reserve University and both a M.Sc. and Ph.D. in Civil Engineering from The George Washington University. Dr. Kildare's responsibilities at Advocates include research on technical issues and safety technology, data analysis, evaluation of safety research studies, and development of policy positions. He represents Advocates at technical and industry meetings and also oversees Advocates' technical statements and comments filed with federal and state agencies.

Before joining Advocates, Dr. Kildare held positions or conducted research with Tier 1 suppliers, manufacturers, independent research organizations, and collision investigation firms. He has authored or co-authored a number of technical papers on a variety of transportation safety topics including vehicle fires, rollover, finite element analysis, accident reconstruction, and injury. Dr. Kildare instructed graduate level studies at The George Washington University and Johns Hopkins University.

STATEMENT OF SHAUN KILDARE, PH.D.

DIRECTOR OF RESEARCH
ADVOCATES FOR HIGHWAY AND AUTO SAFETY

ON

"INNOVATION AND AMERICA'S INFRASTRUCTURE: EXAMINING THE EFFECTS OF EMERGING AUTONOMOUS TECHNOLOGIES ON AMERICA'S ROADS AND BRIDGES"

SUBMITTED TO THE

U. S. SENATE
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

JUNE 13, 2018

Introduction

Advocates for Highway and Auto Safety (Advocates) is a unique coalition of public health, safety, and consumer organizations, insurers and insurance agents that promotes highway and auto safety through the adoption of federal and state laws, policies and regulations. Advocates works to prevent crashes, deaths and injuries through the advancement of safer vehicles, safer drivers and safer roads and infrastructure.

Motor Vehicle Deaths Remain Unacceptably High

According to the federal government, each year motor vehicle crashes kill tens of thousands of people and injure millions more at a cost to society of over $800 billion.[1] According to the latest statistics from the National Highway Traffic Safety Administration (NHTSA), 37,461 people were killed on our nation's roads in 2016. This is an increase of over five percent from 2015, and it[2] follows a seven percent increase from 2014 to 2015.[3]

Advocates Has Consistently Promoted Technology to Save Lives and Prevent Injuries

Advocates has always enthusiastically championed vehicle safety technology and for good reason; it is one of the most effective strategies for preventing deaths and injuries. NHTSA has estimated that since 1960, over 600,000 lives have been saved by motor vehicle safety technologies.[4] In 1991, Advocates led the coalition that supported bipartisan legislation sponsored by Senators John Danforth (R-MO) and Richard Bryan (D-NV) that included airbag technology in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991.[5] As a result, by 1997, every new car sold in the United States was equipped with a front seat airbag and the lives saved have been significant. Over the last decade airbags saved approximately 2,500 lives annually,[6] and have saved an estimated 47,625 lives since 1987, according to NHTSA.[7]

Advocates continued to build on this success by supporting additional lifesaving technologies as standard equipment in all vehicles in other legislation and regulatory proposals. These efforts include: tire pressure monitoring systems;[8] rear outboard 3-point seat belts;[9] electronic stability control;[10] rear seat belt reminder systems;[11] rear view cameras;[12] brake transmission interlocks;[13] seat belts on motorcoaches;[14] and, electronic logging devices for commercial motor vehicles (CMVs).[15] These safety advances have saved hundreds of thousands of lives and many have been accomplished because of the bipartisan leadership of the Members of the Senate. Additionally, crash avoidance systems, such as automatic emergency braking (AEB), are critical to the development of autonomous vehicles (AVs) and could be saving even more lives if the technology was required as standard equipment.[16]

Autonomous Vehicles Need Sensible Safeguards

Advocates believes that AVs have the potential to make significant and lasting reductions in the number of deaths and injuries that occur each year on our Nation's roads. However, deploying AVs before they can be safely operated on public roads and without commonsense government oversight and industry accountability is not only reckless and ill-advised, but it will also substantially reduce public confidence in this new technology.

The Safe Operation of Autonomous Vehicle Systems Has Yet to be Proved

Serious and fatal crashes involving AVs have revealed significant flaws in this still developing technology, including AVs' ability to detect and respond to roadway infrastructure, emergency vehicles, bicyclists and pedestrians. On May 7, 2016, in Williston, Florida, a Tesla Model S on "Autopilot" struck and passed beneath a semitrailer killing the driver.[17] On January 22, 2018, in Culver City, California, another Tesla Model S operating on "Autopilot" collided with a parked fire truck that was responding to the scene of a separate crash.[18] Remarkably, neither the Tesla

driver nor any first responders were injured.[19] On March 18, 2018, in Tempe, Arizona, an Uber test vehicle operating on self-driving mode struck and killed a pedestrian walking a bicycle.[20] Then, just a few days later on March 23, 2018, in Mountain View, California, a Tesla Model X operating on "Autopilot" collided with a safety barrier resulting in the death of the driver.[21] According to the National Transportation Safety Board (NTSB) preliminary report on the crash, the vehicle was being operated under "Autopilot", had moved out of the lane of travel on its own and accelerated to 70 miles-per-hour (MPH) before colliding with the barrier.[22] The collision and subsequent intense fire closed the freeway for at least five hours.[23] Most recently, on May 29, 2018, a Tesla Model S operating on "Autopilot" struck a parked police vehicle in Laguna Beach, California.[24] The NTSB has investigated or is investigating all of these crashes except the last one.

In addition to the tragic crashes that have already happened involving autonomous systems, data accumulated from the limited miles traveled also paints an alarming picture. In 2016, the latest year for which data is available, on average a person was killed in a traffic collision every 84.7 million miles traveled on U.S. roads.[25] Before the fatal crash in Arizona, Uber had reportedly logged 2 million autonomous miles as of the end of 2017 and was predicted to accrue another 1 million miles over the next 100 days.[26] Based on a simple evaluation of this data, the autonomous Uber had one fatality in three million miles; that is a fatality rate 28 times that of human drivers. This analysis highlights just how little proof there is that these systems are safe. The two voluntary safety self-assessments filed with NHTSA illustrate that manufacturers are touting the "millions of miles"[27] or "five million miles"[28] driven by their test vehicles as proof of their systems' safety. However, these numbers pale in comparison to the more than three *trillion* miles traveled by human drivers on U.S. roads each year.[29]

Similar misdirection about safety performance data has been used in response to recent crashes involving AVs. After the 2016 fatal Tesla crash in Florida, the NHTSA Office of Defects and Investigation (ODI) issued a report which included an analysis of data supplied by Tesla that showed "that the Tesla vehicles crash rate dropped by almost 40 percent after Autosteer [a feature of the Autopilot system] installation."[30] However, included in the ODI report was a critical footnote that the crash rates reported were "for all miles travelled before and after Autopilot installation and are not limited to *actual Autopilot use*" (emphasis added).[31] Despite this clear statement by NHTSA, Tesla continues to mischaracterize the ODI analysis in response to subsequent fatal crashes involving vehicles operating under the "Autopilot" system.[32] NHTSA has since clarified again that the effectiveness of the "Autopilot" system was not evaluated in its prior investigation, refuting the claims by Tesla.[33] Moreover, Tesla was removed as a party to the NTSB investigation of the second fatal crash involving one of its vehicles shortly after a March blog post once again made this same claim.[34]

These types of details matter when it comes to AVs, particularly when evaluating claims are made to support their introduction. Some members of the industry assert that waiting for AV technology to be perfect would be "the enemy of the good."[35] In some cases, they point to a report of the same title by the Rand Corporation (RAND) to bolster this argument.[36] In fact, the RAND report concluded that allowing the deployment of AVs, which have a safety performance that is just 10 percent better than that of the average human driver, would save more lives than waiting for a perfectly safe AV.[37] However, the critical underpinning of this statement, which is being widely missed in the use of this report, is that these vehicles are in fact demonstrably better, even in some minute amount, than human drivers. It is essential to note that this is a fact

which has yet to be proved. The industry and regulators have yet to agree on the proper metrics for evaluating the safety performance of an AV, let alone requirements for operation which would assure that these vehicles are ten percent, one percent, or even a tenth of a percent better than the average human driver.

Federal Vehicle Safety Standards Have Both Immediate and Long Term Benefits

Advocates has always supported the introduction of safety technologies once its benefits have been identified and verified. Often additional advantages arise out of the widespread implementation of the base technology. For example, Advocates evaluated an abundance of research and data demonstrating that installing a rearview camera in passenger vehicles would help to prevent backover crashes and resultant deaths and injuries, often to young children and disabled persons.[38] Advocates, together with others in the safety community especially KidsAndCars.org and the remarkable families of backover victims, then fought for a decade in total to ascertain a rearview camera requirement for all new vehicles, which recently took effect on May 1, 2018. The Insurance Institute for Highway Safety (IIHS) conducted research, published in their November 17, 2016 *Status Report*, demonstrating additional benefits of rearview cameras such as reducing property damage crashes during backing, and assistance with backing maneuvers such as parking.[39] Furthermore, if a video sensor stream was required, including additional driver assistance technologies such automatic rear braking, parking guidance, and even automated parking assistance, even more advantages could be realized.

Similarly, Advocates supported equipping vehicles with anti-lock braking systems (ABS), which helps a driver to maintain control of the vehicle when braking on slippery surfaces. ABS has also resulted in wide ranging benefits. In fact, ABS is the base technology for electronic stability control (ESC) which helps to prevent rollover and loss of control crashes and is attributed to

having saved more than 7,000 lives since 2011.[40] Automatic emergency braking (AEB), which uses on-board sensors such as radar, cameras or lasers to detect an imminent crash, warns the driver and applies the brakes or increases the braking effort if the driver does not take sufficient action. The applications which are in ABS and ESC are also an underlying technology for AVs.

A critical component of both of these safety successes is a federal standard that ensures these technologies have a specific level of performance so that consumers can have confidence in the technology as well as familiarity with a new feature of their vehicle. Federal standards also pave the way to build public acceptance and use of these technologies which magnifies the safety benefits. In sum, effective government oversight and performance standards are critical to the success of new safety technologies placed into motor vehicles.

Examples of the success of effective standards and oversight of automated systems fly over our heads every single day. According to the U.S. Bureau of Transportation Statistics, 741 million passengers traveled on domestic flights in 2017.[41] The tragic April 2018 death of a Southwest Airlines passenger was the first U.S. commercial airline fatality since 2009.[42] Over that same span of time (2010-2017), nearly 5.4 billion passengers travelled safely through our skies. The Federal Aviation Administration (FAA) estimates that airline pilots use automated systems 90 percent of the time while flying.[43] Meanwhile, on our roads from 2010 to 2017, crashes claimed the lives of approximately 275,000 road users.[44] The federal government, and the U.S. Department of Transportation (DOT) in particular, already have experience in developing standards and implementing effective oversight of autonomous systems in transportation. While adaptation for governing AVs on roads is necessary, this is not an entirely new concept. The U.S. DOT would do well to coordinate with other departments and its own agencies, and make

the best use of its past research, current regulations, and the latest technologies to set standards ensuring the safe introduction of AVs.

Federal Standards are Especially Critical Considering Public Opinion Polls Show Skepticism about AVs

Numerous public opinion polls show strong public skepticism and reticence about AVs.[45] Those doubts are warranted based on the recent crashes and the past conduct of automakers. Over the last few years, automakers have hidden from the American public and regulators safety defects which have led to numerous unacceptable and unnecessary deaths and injuries as well as the recall of tens of millions of vehicles.[46] Consumer acceptance of AV technology is critical to its success and to fully realizing the lifesaving potential of AVs. In January of 2018, Advocates commissioned an independent public opinion poll that revealed intense apprehension regarding the widespread deployment of AVs. In fact, two-thirds of respondents (64%) expressed concern about sharing the roads with driverless cars.[47] When asked if they support DOT developing safety standards for new features related to the operation of driverless cars, 73% responded affirmatively.

Other surveys have yielded similar results. In a May 2018 poll commissioned by the American Automobile Association (AAA), 73% of American drivers said they would be too afraid to ride in a fully self-driving vehicle, up from 63% in late 2017.[48] A Reuters/Ipsos poll found that 67% of Americans were uncomfortable with the idea of riding in self-driving cars.[49] Lastly, in a May 2018 Public Policy Polling/Consumer Watchdog poll, 80% of respondents agreed that federal and state governments should regulate driverless vehicles for the safety of riders, pedestrians and other drivers.[50] To realize the safety benefits promised by the deployment of AVs, public acceptance and support are needed. Right now families know that when they go into auto

showrooms to buy a new car, the federal government has protections in place to ensure their safety. Similar oversight and regulation are needed for AVs to both assure and safeguard consumers.

Upgrades to America's Infrastructure Are Required for the Safe Deployment of Autonomous Vehicles

According to the American Society of Civil Engineers (ASCE), one in eleven of the Nation's nearly 615,000 bridges in the National Bridge Inventory are structurally deficient.[51] America's roads continue to receive a grade of "D" from ASCE which noted that 20 percent of the Nation's highways alone had poor pavement conditions in 2014.[52] This does not include those highways with mediocre conditions and all other non-highway roads.[53] The Federal Highway Administration (FHWA) estimates that $142 billion in capital investment would be needed on an annual basis over the next 20 years to significantly improve conditions and performance.[54] Undoubtedly, additional substantial investments in our infrastructure will be required to ensure that AVs can safely operate on America's roads.

Infrastructure design and implementation is currently guided by a library of manuals such as the Manual on Uniform Traffic Control Devices, the American Association of State Highway and Transportation Officials (AASHTO) "Green Book", the Highway Safety Manual, and the Transportation Research Board (TRB) Highway Capacity Manual, to name just a few. In many cases, these documents provide guidance which is open to engineering interpretation at the federal, state, and local levels to enable roadway designs to adapt to specific conditions or requirements. Federal oversight will be critical to ensure uniformity. However, the linchpin for much of the guidance in these manuals is human performance behind the wheel. From sight distances for signs, to lettering, to the curvature and super elevations of roads, the design criteria

of our infrastructure has understandably been developed to enable the safe operation of vehicles by human drivers. With the introduction of AVs, much of the basic premises may change and have to serve a dual purpose while a mixed fleet of both human and machine driven vehicles exist side-by-side for decades to come.

AVs will not be operating in a vacuum or closed environment. Instead, they will be operating on public roads and that is why ensuring that our Nation's infrastructure can accommodate the safe and successful deployment of AVs is so important. "Stand-alone" AVs (those that will not communicate with other vehicles) will be limited by the capability of the sensors installed in the vehicle and therefore, will largely suffer from the same types of limitations that afflict human drivers. If an AV's camera, or radar, or lidar cannot "see" an object, the AV cannot respond to its presence whether it is an emergency vehicle, a bicyclist or a baby stroller. Likewise, if the AV cannot decipher what an object is, even if it has seen something, the AV will have trouble responding to its presence. In the 2016 Tesla crash in Florida, the "Autopilot" system was unable to identify the truck crossing the path of the vehicle and thus did not respond.[55] In January of this year, a Tesla reportedly on "Autopilot" struck the rear of a fire truck stopped on a freeway which was responding to a separate incident.[56] In the fatal Tesla crash that occurred just two months later in Mountain View, California, it appears that the "Autopilot" system failed to maintain lane position before striking a crash attenuator.[57] Each of these highly publicized crashes illustrates some aspect of how infrastructure changes could improve the safety and performance of AVs, as described below, yet those upgrades are likely many years away.

Connected Vehicles

Connected vehicle technologies allow a vehicle to send and receive communications with other vehicles (vehicle-to-vehicle (V2V)) and the infrastructure (vehicle-to-infrastructure (V2I)).

These messages can relay information ranging from the relative location and direction of motion of other vehicles to warning messages that traffic lights are about to change or weather conditions are soon to be encountered. These systems will likely help fill in gaps in the performance of AVs. For instance, V2V communication can provide safety applications for advanced driver-assistance systems (ADAS) such as Left Turn Assist (LTA) and Forward Collision Warning (FCW). LTA warns drivers to the presence of oncoming, opposite-direction traffic when attempting a left turn. FCW warns drivers of stopped, slowing or slower vehicles ahead. In a 2017 Notice of Proposed Rulemaking to require V2V technology, NHTSA noted that "[b]ecause of V2V's ability to provide vehicles with information beyond a vehicle's range of perception, V2V is the only source of information that supports applications like Intersection Movement Assist (IMA) and Left Turn Assist (LTA). These applications have the unique ability to address intersection crashes, which are among the most deadly crashes that drivers currently face in the U.S."[58]

These technologies surely would have been of use in the fatal crash in Florida between the Tesla and the left turning tractor trailer, and the California crash where the Tesla struck the rear of a stopped fire truck. Likewise, V2I applications could have provided information to the vehicle in the California crash about the emergency response underway on the highway, or in the Florida crash to inform the Tesla that it was operating on a road outside of the AV's operating design domain (ODD) where it was intended to operate. The International Association of Fire Chiefs submitted comments endorsing a federal requirement for V2V technology, noting the significant number of firefighter deaths and injuries coming from crashes.[59] Advocates also filed comments in support of mandating V2V because of the technology's ability to help prevent serious

crashes.[60] However, despite the identified safety benefits of V2V technology, this rule is languishing at DOT.

Road Design

As noted above, the design of our roads from the asphalt, to the signage, to the lighting, to the speed limit is largely based on the history of human performance behind the wheel and the capability of the vehicles. The introduction of AVs stands to essentially require a re-write of many of these guidelines in the future. However, in the near term, there will need to be an evaluation of how standards for design can be modified to accommodate both human and machine "drivers". The recent Tesla crash in California highlights how both human and machine "drivers" could benefit from improved lane marking as well as establishing standards for pavement resurfacing to ensure that repair seams and color differences do not confuse AV systems. Establishing uniform standards for signage color, lighting, contrast, letter size, and other roadway features will also reap similar benefits. Many of the current manuals' guidelines and recommendations are almost always open to engineering interpretation. With the advent of AVs, more emphasis must be placed on consistency, and consideration must be given to the effects variations can have on autonomous technology. While a human driver can see a unique situation and interpret those circumstances fairly well, an AV may not be able to do the same. Research has already shown that minor distortion of a sign can cause havoc for AVs, causing stop signs to be interpreted as speed limit signs, a confusion which can have serious, and even potentially fatal, results.[61]

Roadway deterioration and delayed repair, which are common occurrences on existing infrastructure, will have a negative impact on AV operation. Every driver has experienced road signs or markings that have been damaged, intentionally altered or blocked by objects. This

could lead to misinterpretation of highway cues and result in stopped or misdirected AVs that will present dangerous highway hazards. These findings and similar research illustrate not only that standards for roadway design can be critical to performance, but also that road design improvements alone may not suffice to ensure the safe operation of AVs. Combining standards for design with infrastructure improvement like V2I would help to provide additional awareness for human drivers and unambiguous inputs for machine "drivers."

America's crumbling infrastructure poses significant safety and economic concerns. The AV industry has often claimed that the introduction of these vehicles will reduce congestion, improve environmental quality, and advance transportation efficiency.[62] However, many of these claims may amount to nothing more than fanciful theories. Instead, AVs may bring about so-called "hyper-commuters" who work from their vehicles on long commutes to enable living further from offices and/or city centers. Likewise, the possibility of empty AVs adding substantial miles on the roads as they re-position autonomously after dropping off riders could undermine many of the benefits claimed.[63] Significant consideration must be given to how AV driving could change wear patterns on roadways. The lower variance of an AV's position within a lane could lead to accelerated wear in lanes, and condensed convoys of automated trucks, commonly known as platooning, could place further strain on roads and bridges. All of these concerns must be evaluated to consider operational constraints for AVs before further damage is inflicted upon our Nation's roads and bridges. For example, the spacing between automated commercial motor vehicles (ACMVs) in a platoon could have wide ranging implications. If these large vehicles travel too closely together, their combined weight load could place severe stress on a bridge. In addition, lengthy platoons that consist of many ACMVs could be difficult to pass and affect merging and exiting from roadways.

Taking into account the long term ramifications, the budgetary constraints, and necessary coordination among a diverse group of interested parties when it comes to infrastructure projects at any level, research is needed now more than ever on the impact of AVs on our roads. Large comprehensive studies of the implications of the introduction of AVs such as the National Cooperative Highway Research Program Project 20-102 are necessary to identify the strengths of the current infrastructure, but more importantly where coordination and standards need to be improved or created. The project astutely noted in one of its reports that "the line between vehicle regulations, infrastructure and operations is further blurred" when road standards are needed to enable the safe operation of AVs.[64] This statement underlines how critical infrastructure improvements are going to be to the safe deployment of this new technology. In addition, further research is also required to examine the differing infrastructure upgrades that will be required for urban, suburban and rural regions. More consideration must be given to this complex issue before AVs can be deployed on a large scale.

In Addition to Infrastructure Upgrades, Proper Government Oversight is Needed for the Safe Deployment of Autonomous Vehicles

Over fifty years ago, Congress passed the National Traffic and Motor Vehicle Safety Act of 1966 because of concerns about the death and injury toll on our highways.[65] The law required the federal government to establish minimum vehicle safety performance standards to protect the public against "unreasonable risk of accidents occurring as a result of the design, construction or performance of motor vehicles."[66] While motor vehicles have changed dramatically since that time and will continue to do so in the future, the underlying premise of this crucial law and NHTSA's safety mission have not.

Unfortunately, NHTSA has chosen to issue only "voluntary guidelines" for the development of AVs.[67] Voluntary guidelines are not enforceable because they are not legally binding, and, therefore, are inadequate to ensure safety and protect the public. Manufacturers may unilaterally choose to deviate from the guidelines or ignore them entirely at any time and for any reason including internal corporate priorities such as cost or marketing considerations.

The AV START Act Fails to Ensure Public Safety

Compounding NHTSA's inaction are the deep flaws of The American Vision for Safer Transportation through Advancement of Revolutionary Technologies (AV START) Act (S. 1885) currently pending before the Senate. We are disappointed that the bill, in its current form, falls well short of the oversight and accountability necessary to ensure public safety. Moreover, the bill unnecessarily takes aim at the current federal regulatory scheme that has been in place for decades protecting those traveling on America's roads. We continue to push for reasonable improvements to the bill. Furthermore, for the Senate to fully consider all of the public safety implications associated with the mass deployment of AVs, the AV START Act should not move forward until the ongoing multiple investigations by the NTSB of the serious and fatal crashes involving AVs noted above are completed.

Section 6 of the AV START Act will allow millions of vehicles to be deployed into the public domain that are exempt from existing critical Federal Motor Vehicle Safety Standards (FMVSS). Providing broad statutory exemptions from the FMVSS for AVs is both unnecessary and unwise. There is already a statutory process in place for manufacturers to seek an exemption from the FMVSS. Moreover, Section 24404 of the Fixing America's Surface Transportation (FAST) Act[68] permits auto manufacturers to test or evaluate an unlimited number of vehicles exempt from one or more of the FMVSS.[69] Furthermore, the exemption provision in current law, 49

USC Section 30113(a), provides that manufacturers may receive an exemption from compliance with the FMVSS for the sale of 2,500 vehicles to be sold in the United States in any 12-month period. No evidence has been presented to show that the development and deployment of AVs requires wholesale exemptions for an untold number of AVs from critical federal safety standards that are essential to protecting public safety.

Additionally, the legislation currently contains no prohibition on AVs receiving an exemption from crashworthiness or occupant protection standards which protect the vehicle's passengers. Such exemptions can diminish the level of occupant protection that has been established through years of research under the existing regulations.[70] Prohibiting such exemptions will in no way inhibit the development of AV technology but will ensure that passengers of AVs are properly protected in a crash.

Section 7 of the AV START Act drastically alters current federal law which prohibits manufacturers from rendering safety systems, such as the brakes and brake pedal, inoperable. This provision is a dangerous change in settled law because it would allow automakers to "turn off" safety systems while the AV is being driven by the computer. This could unnecessarily dilute safety at the discretion of the manufacturer and sets a precedent of Congress allowing manufacturers to unilaterally circumvent many of the existing safety standards. Currently, automakers cannot turn off safety systems without government oversight.

Section 9 of the AV START Act requires manufacturers of AVs and AV technology to submit to NHTSA a Safety Evaluation Report (SER) that details the development of the technology and its expected performance in real world conditions. While Advocates supports the mandatory

submission of such information, this provision as currently written only directs manufacturers to "describe" their AV systems. In the absence of a legislative directive to require that sufficient information and data are included in the SER, manufacturers will continue to submit slick marketing brochures such as those already released by two manufacturers[71] instead of providing data and documentation that will allow the public and NHTSA to accurately evaluate the safety of the technology.

The AV START Act should ensure that consumers are given essential information about an AV. Every manufacturer should be required to provide each consumer with information about the capabilities, limitations and exemptions from safety standards for all vehicles sold in the U.S. at the time of sale. This information should be made available to consumers from day one, even before NHTSA issues a rule. Additionally, it would be useful for consumers and researchers to be able to automatically identify AVs by the vehicle identification number (VIN).

NHTSA should also be required to establish a public website with basic safety information about AVs for consumers and for use in safety research. This online database would be similar to the safercar.gov website that NHTSA maintains to inform the public about safety recalls applicable to their vehicle. This would enable consumers to enter their VIN to obtain critical information about their AV such as the level of automation, any exemptions granted by NHTSA from the FMVSS, and the operational design domain which includes limitations and capabilities of each autonomous driving system with which a vehicle is equipped. Such a database will be critical for consumers who purchase AVs and will also allow NHTSA and other research groups to perform independent evaluation of the comparative safety performance of AV systems.

Additionally, data sharing among manufacturers is essential to improve overall safety among AVs. Data and information about known flaws or problems encountered during development and while in use must be shared among manufacturers and with NHTSA and the public to ensure that all AV systems are learning about problems in real time and can benefit from the experience of other AV systems. This type of collaborative development is already taking place in the industry with respect to cybersecurity issues with the creation of the Automotive Information Sharing and Analysis Center (Auto ISAC). Data sharing will expedite solutions to unusual or unique safety problems and ensure they are readily identified and corrected. The NTSB in their investigation of the fatal Tesla crash in Florida noted that event data recorders (EDRs) are not required nor would current standards mandate the capturing of data necessary to evaluate the performance of AVs. The AV START Act does not require that this critical safety data generated by AVs will be recorded, shared or even provided to NHTSA. It is also essential that the legislation require all crashes involving AVs be reported immediately to NHTSA by manufacturers.

Commonsense Improvements Must Be Made to the AV START Act

Without essential changes and additions to AV START Act, this legislation, which will establish our Nation's AV policy for years to come, will needlessly put all road users at risk. The additional improvements outlined below will not inhibit the development and deployment of AVs. Rather, these commonsense recommendations will ensure public safety and industry accountability.

Include Level 2 AVs

The AV START Act does not include Society of Automotive Engineers (SAE) Level 2 AVs, which require a human driver monitor their performance and be available to take over the driving

task when necessary, like the Teslas which have been involved in several crashes. During a September 12, 2017, hearing on the 2016 crash conducted by the NTSB, deadly failures of Tesla's Level 2 "Autopilot" system were readily identified.[72] The NTSB found that similar problems also exist in other Level 2 AVs across many manufacturers.[73] In the near term, Level 2 AVs will likely comprise a majority of the passenger vehicle AV fleet. Proper safeguards to curb Tesla-like failures must be put in place. At a minimum, Level 2 AVs should be covered by the SER, consumer information disclosure and cybersecurity provisions in the AV START Act.

Require Cybersecurity Standards

A failure to adequately secure AV systems and to protect against cyber-attacks could endanger AV passengers, non-AV motorists, pedestrians, bicyclists and other vulnerable roadway users. It could also clog roads, stop the movement of goods and hinder the responses of emergency vehicles. The real possibility of a malevolent computer hack impacting hundreds or thousands of AVs, perhaps whole model runs, makes strong cybersecurity protections a crucial element of AV design. Yet, Section 14 of the AV START Act merely requires manufacturers to have a cybersecurity plan in place with no minimum standards of protection or effectiveness. Instead, the legislation should require NHTSA to establish a minimum performance standard to ensure cybersecurity protections are required for AVs of all levels. Considering the recent record of high-profile cyber-attacks,[74] allowing manufacturers merely to have a cybersecurity plan in place is grossly inadequate to ensure that AVs are protected against potentially catastrophic cyber-attacks and breaches.[75]

Direct NHTSA to Proscribe Standards to Prevent Driver Distraction

In AVs that require a human to take control from the AV system (Levels 2 and 3), the automated driving system must keep the driver engaged in the driving task. Research demonstrates that

even for a driver who is alert and performing the dynamic driving task, there is a delay in reaction time between observing a safety problem and taking appropriate action.[76] For a driver who is disengaged from the driving task during autonomous operation of a vehicle, that delay will be longer because the driver must first be alerted to re-engage, understand the situation, then take control of the vehicle before taking appropriate action. The failure of the automated driving system to keep the driver engaged in the driving task during the trip was identified as a problem by the NTSB Tesla crash investigation. The NTSB found that the Tesla "Autopilot" facilitated the driver's inattention and overreliance on the system, which ultimately contributed to his death.[77] The "Autopilot" was active for 37 minutes of the 41 minute trip and during the 37 minutes, the system detected the hands on the steering wheel only 7 times for a total of 25 seconds.[78] The NTSB also found that these problems are widespread across manufacturers with similar systems.[79] The AV START Act fails to address this critical safety problem, yet technology to discern distraction and provide alerts is already available, and NHTSA should be directed to establish a minimum performance standard to ensure driver engagement throughout the trip.

Provide for Standards to Protect the Electronics that Power Safety Systems

Motor vehicles and motor vehicle equipment are powered and run by highly complex electronic systems and will become even more so with the future deployment of autonomous driving systems. Interference from non-safety systems can affect the electronics that power critical safety systems if they share the same wiring and circuits. For example, in one reported instance a vehicle model lost power to its dashboard lights when an MP3 player was plugged in and used.[80] Similar to FAA requirements to protect the electronics and their functions in aircraft under any foreseeable operating condition,[81] NHTSA should require minimum performance standards for the electronics in all motor vehicles, particularly AVs. However, the AV START

Act fails to direct NHTSA to develop and issue performance standards for the electronics systems of modern motor vehicles as the FAA does for aircraft which, like AV cars, are highly dependent on electronic systems.

Require an AV "Vision Test" to Ensure Operating Safety

In order for an AV to properly interact with its surrounding environment, it must not only detect other vehicles and roadway infrastructure but also other participants using our Nation's transportation systems such as pedestrians, bicyclists, wheelchair users, construction workers in work zones, first responders providing assistance after crashes, and law enforcement officers directing traffic. A failure to properly detect and react to any of these could have tragic results similar to the recent Tesla crash where the vehicle while operating on the "Autopilot" system reportedly drove into a roadside barrier.[82] AVs and automated driving systems must be subject to objective testing to ensure that they properly detect other road users, as well as pavement markings and infrastructure, can correctly identify the type of object that has been detected, and can then also respond properly and safely. Therefore, the AV START Act should direct the Secretary to initiate a rulemaking proceeding to require automated driving systems, including SAE Level 2 automated driving systems, to meet a minimum performance standard for detecting and reacting to the AV's driving environment.

U.S. DOT Requires Sufficient Funding and Authority to Properly Regulate Automated Vehicles

Regulating AVs presents unique challenges for the U.S. DOT, and those issues warrant additional tools and funding to protect against potentially catastrophic defects and failures. NHTSA should be granted imminent hazard authority in order to expedite the grounding of vehicles that the agency has identified as having a potentially dangerous, widespread problem or when it detects a cybersecurity threat that could lead to inordinate crashes, deaths and injuries.

Additionally, because of the potential serious nature of software defects that could imperil safety in thousands of vehicles, the ability to levy enhanced penalties is essential. The unacceptable level of current motor vehicle crashes, fatalities and injuries combined with the demands being placed on NHTSA with regard to AV technology necessitates an increase in agency funding.

Today, 95 percent of transportation-related fatalities, and 99 percent of transportation injuries, involve motor vehicles on our streets and highways.[83] Yet, NHTSA receives only one percent of the overall DOT budget.[84] The AV START Act requires NHTSA to take on new significant responsibilities. In order to efficiently execute all of these tasks, an office dedicated to AV safety should be established within NHTSA. The protection of public safety should not be compromised and progress should not be slowed because the agency does not have adequate technical expertise, organization, resources and funding to oversee the development and deployment of AVs.

Moreover, it is the statutory mission of NHTSA to regulate the design and performance of motor vehicles to ensure public safety which, in modern day terms, includes AVs and automated driving system technology. However, in the absence of comprehensive federal standards and regulations to govern the AV rules of the road, the states have every legal right, indeed a duty to their citizens, to fill the regulatory vacuum with state developed proposals and solutions for ensuring public safety.

Lastly, additional funding for infrastructure upgrades to accommodate AVs will likely need to be authorized as driverless cars are deployed so that states can make the requisite improvements to their roadways.

Conclusion

Every day on average 100 people are killed and 6,500 more are injured in motor vehicle crashes in the U.S. Advocates has consistently promoted technology to reduce this unacceptable death and injury toll. So too, does Advocates believe that automated technology has the potential to make significant and lasting reductions to this public health epidemic. However, AVs should not be prematurely deployed and sold before they can be safely operated on public roads and without commonsense government oversight in place. Serious and fatal crashes involving AVs which have already occurred reveal significant flaws in this still developing technology. These crashes have also shown that coordination at the federal, state and local levels regarding infrastructure development and upgrades will play a significant role in the safe and successful development of AVs. Synchronization by governing bodies and safeguards are essential to turn around the current skepticism widely held by the public to build trust. In sum, the path to the safe and effective introduction of AVs must require government oversight, transparency and a comprehensive regulatory framework in all aspects from vehicle standards to infrastructure design.

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Senate Committee on Environment and Public Works
Hearing entitled, *"Innovation and America's Infrastructure: Examining the Effects of Emerging Autonomous Technologies on America's Roads and Bridges."*
June 13, 2018
Questions for the Record
Dr. Shaun Kildare, Director of Research

Ranking Member Carper:

1. *Early, high-profile crashes of autonomous vehicles have sowed public concerns and potentially distrust of autonomous vehicle technology. What improvements to the infrastructure necessary to support autonomous vehicle technology must occur in order to ensure that deployment of AVs builds public confidence? Specifically, what steps can the EPW Committee take to ensure that infrastructure helps to support the safe operation of these vehicles?*

The Committee on Environment and Public Works (EPW) could direct the Federal Highway Administration (FHWA) to establish a new program to ensure collaboration among infrastructure experts including suppliers, manufacturers, test facilities, infrastructure owners and operators, engineers and safety consultants to develop research priorities to determine which improvements are critical to the implementation of connected and autonomous vehicles (AVs) while also benefitting human drivers. The agency should then be required to undertake this research and include identified necessary improvements in their priorities moving forward. Federal leadership will be necessary to research and execute improvements to aspects of infrastructure such as pavement marking, road design standards and signage. Moreover, leadership from the federal government to set standards for the safety and performance of AVs, and require relevant data recording and reporting, will be essential to set the baseline for the development of associated infrastructure needs. The limited funds available for infrastructure improvements necessitate that every federal dollar be spent wisely to avoid costly mistakes which can hinder the eventual benefits expected to be realized from the introduction of AVs.

2. *Given that the House and Senate AV bills provide NHTSA with new exemption authority to permit thousands of AVs on the roads while also preempting states from regulating AVs, are there minimum infrastructure conditions, design changes, or Vehicle-to-Infrastructure connectivity policies that need to be established at the national level? Should these changes be implemented before widespread deployment occurs?*

Both the House and Senate AV bills essentially eviscerate the current federal regulatory scheme that has been in place for decades to ensure the safety of motor vehicles traveling on America's roads. A strong regulatory framework for AV technology can be expeditiously developed and

will ensure that public safety is not jeopardized. Rather, the pending legislation would allow for broad statutory exemptions from the Federal Motor Vehicle Safety Standards (FMVSS) for AVs – a move that is both unnecessary and unwise. There is already an established process in place for manufacturers to seek an exemption from the FMVSS which Congress amended only three years ago. Section 24404 of the Fixing America's Surface Transportation (FAST) Act (Pub. L. 114-94) permits auto manufacturers to test or evaluate an unlimited number of vehicles exempt from one or more of the FMVSS. Exempt vehicles under this provision may not be sold or resold to the public. However, the exemption provision in current law, 49 USC Section 30113(a), provides that manufacturers may receive an exemption from compliance with the FMVSS for 2,500 vehicles to be sold in the United States in any 12-month period. There has simply been no demonstrable evidence presented that the development and deployment of AVs requires further expansion of these limits on vehicles that can be exempt from critical federal safety standards which are vital to protecting public safety.

Furthermore, the legislation currently contains no prohibition on AVs receiving an exemption from crashworthiness or occupant protection standards which protect the vehicle's passengers. Such exemptions can diminish the level of occupant protection that has been established through years of research under the existing regulations. For example, removing the steering wheel should not eliminate the requirement to protect the occupant from injury using safety systems such as airbags. Prohibiting such exemptions will in no way inhibit the development of AV technology but will ensure that passengers of AVs are properly protected in a crash.

Advocates agrees with the statutory mission of NHTSA to regulate the design and performance of motor vehicles to ensure public safety which, in modern day terms, includes AVs and automated driving system technology. However, in the absence of comprehensive federal standards and regulations to govern the AV rules of the road, the states have every legal right, indeed a duty to their citizens, to fill the regulatory vacuum with state developed proposals and solutions for ensuring public safety. NHTSA, by issuing only voluntary guidelines, has left the field of AV safety open to the states to fulfill their traditional role of protecting the health and welfare of their citizens.

In addition, as noted above coordinated research led by the federal government will be necessary to ensure that standards for infrastructure conditions, design, and improvements (including V2X) are established before widespread introduction of AVs to ensure that their potential benefits are realized.

3. *In aviation and surface transportation settings, pilots and drivers must be certified to operate vehicles through a licensing process. Given the variation in how AV technologies operate and detect the roadside environment through probabilistic reasoning, should there be a similar licensing approach to certify that AVs are adequately prepared to detect the roadway signs, markings, infrastructural elements, and other users of the road? If yes, how so? If no, how might we otherwise ensure that in complex urban environments, for example, that highly autonomous vehicle technology is prepared to operate safely and effectively?*

Advocates believes that a measured and prudent approach to testing, validation, and verification of the safety performance of AVs is necessary before widespread public introduction of these vehicles. Unfortunately, the AV START Act does not compel such an approach. It does not direct the United States Department of Transportation (U.S. DOT) to set any performance standards for the operation of AVs. Advocates recommends the bill be changed to mandate that U.S. DOT issue reasonable safety standards for AVs as they are developed and deployed.

One such necessary standard is a "vision test". It will be crucial for AVs to react to the dynamic conditions on the road. Therefore, they must have the capability to observe and recognize the objects around it, be it a road sign, pedestrian, bicyclist, motorcyclist, person in a wheelchair, car, fire truck, tractor trailer, or even roadside hardware. Additional standards to address important factors such as cybersecurity, vehicle electronics and driver engagement will also be crucial.

Recent crashes involving vehicles with varying degrees of autonomy illustrate the nascent state of the technology. The inability of an AV system to respond to everyday conditions on our roads such as stopped emergency vehicles, crossing traffic, pedestrians and poor lane lines, is clear evidence that these systems are not ready to be unleashed on the public. The introduction of AVs should be done in a measured approach, starting on a closed test track and then with a gradual introduction into limited operating conditions until safe performance is established and a justification for expanding the operational domain can be made. This process minimizes both the risk of harm to the public and the risk of harm to the reputation of the technology. Advocates believes that AVs have the long-term potential to improve public safety. However, we are clearly not there yet. Continued crashes and failures, including the loss of life, will erode public confidence, a fact which has already been illustrated in numerous national opinion polls, including one commissioned by Advocates and released this week. *(See attached.)*

4. *A significant number of roadway fatalities in this country occur on rural roads. One of the biggest challenges regarding the use of connected and automated vehicles is the lack of required infrastructure features to accommodate them in rural parts of the country. What can and should we be doing to prepare rural America for the expanded use of AVs?*

AV proponents tend to use three main arguments when justifying the rapid introduction of AVs: first that safety will dramatically improve, second that AVs will have beneficial environmental impacts, and third that AVs will improve the mobility of Americans especially those currently underserved. However, as noted above, there are concerns that many regions of the country, and certain segments of society, will be left behind. Advocates believes that the safety of this technology as well as the assurance that it will provide broadened access to mobility have yet to be proven. Additional research is necessary to ensure that preparations for the introduction of connected and autonomous vehicles are done in an appropriate manner so that the limited infrastructure funds available are spent wisely.

There are many unique transportation characteristics present in rural America that will affect the performance of, and access to, AVs. For instance, necessary technological infrastructure such as broadband connectivity and up-to-date mapping may be limited. Further, maintenance of

roadway markings, signs and pavement may vary. Additionally, unpaved roads in rural areas could increase sensor fouling which could degrade or prevent safe operation. Many AVs will not be confined to certain geographic locations, so their ability to function safely in all road conditions will be necessary. This reality underscores the need for robust testing in all areas of the country, including rural America.

In the meantime, there are a number of safety technologies already available which should be mandated for all vehicles. These technologies would help address a number of rural crashes while providing important data to support the development of connected and autonomous vehicles. Technologies such as automatic emergency braking, lane departure warning, lane keeping assist, and automatic dimming headlamps are just some of the technologies with proven safety benefits that have yet to be mandated by the NHTSA. Moreover, many of these technologies are "building block" components of AV systems that may in-and-of themselves be able to prevent crashes. If AV suppliers truly desire to immediately improve safety, these technologies should be made standard equipment in all vehicles now.

5. *Truck platooning could be one of the earliest forms of automation technology to be broadly adopted on our nation's roadways. This technology allows trucks to run close to one another in a caravan formation. From an infrastructure perspective, this creates the potential for trucks to use roads more efficiently. On the other hand, bridges have been designed for greater spacing between heavy trucks; therefore more needs to be learned on whether bridge spans can safely handle the added weight. What research has been done into the impact that platooning could have on the structural integrity of our bridges? How many platooned trucks do you think most bridges could reasonably hold? Do you think there should be a limit to the number of vehicles allowed in a platoon in order to avoid this damage to our nation's infrastructure?*

Advocates is concerned with a number of issues presented by truck platooning. In order to achieve any efficiency benefits, the trucks in a platoon must operate much closer together than is current practice. This presents very real safety concerns. Issues such as vehicle maintenance may hamper the ability to execute these types of operations outside of controlled experiments. In real-world scenarios, realities of brake and tire maintenance as well as vehicle loading can all affect handling capability. Currently, one in five heavy vehicles inspected at the roadside are placed out of service for vehicle issues, a large number of which are related to brakes or tires. Moreover, until the first vehicle in a platoon is operated by a verifiably safe automated driving system, the safety of the platoon relies on the lead human driver. There are also questions concerning the interaction of platoons with other road users, including the ability of other vehicles to pass a platoon safely or navigate between them if need be in order to reach an exit or enter a road safely.

From the infrastructure standpoint, Advocates agrees that there are a number of uncertainties surrounding the impact of platoons on bridges and roadways. Whether the nation's bridges are able to withstand the new loading associated with closely packed trucks in a platoon is a question for research, and was a topic of discussion at the recent Transportation Research Board (TRB) meeting in January. One of the concerns with platooning is that it may not be covered by the engineering assumptions on traffic density and loading cases which were used when our bridges

were designed. This reality may cut into the factor of safety built into these bridges or overcome it entirely.

What we do know is that the American Society of Civil Engineers (ASCE) has rated our nation's bridges a "C+." ASCE has further noted that four in every ten bridges is 50 years or older, and just over nine percent of bridges are structurally deficient. Advocates is aware that in some current platoon testing, the bridges along specified routes are evaluated and depending on those results it may be necessary to require trucks within a platoon to separate to traverse a span safely. However, such necessary operational constraints very well could severely impact the efficiencies promised by such a practice. Finally, ASCE has noted that the most recent estimated cost for bridge rehabilitation in the U.S. was more than $100 billion. With so many unknowns, it would appear that the most prudent course of action would be to continue to study and resolve these unanswered questions before creating substantial safety and economic impacts on our nation's roads and bridges.

6. *What should transportation planners begin doing now to accommodate AVs? How long will such planning and implementation require?*

As the Members of the Committee know all too well, infrastructure spending is generally on an extended timeline with projects planned out a number of years in advance. Additionally, we will also be operating in a mixed-fleet (human and machine driven) environment for likely decades to come. For this reason, it is important that planners account for the needs of both human and computer driven vehicles. Additionally, the linchpin for much of the guidance in numerous infrastructure manuals is a human behind the wheel. From sight distances for signs, to lettering, to the curvature and super elevations of roads, infrastructure design criteria has been developed to enable the safe operation of vehicles by human drivers. AVs will likely necessitate that these basic premises be modified to reflect the changing fleet on our roads. Research is needed to identify what infrastructure improvements, as part of a cohesive framework for AVs and overall safety, should be undertaken now to improve safety for both types of drivers.

7. *In Japan, the Japanese government is leading testing of AVs, which is currently restricted to major limited access highways rather than on urban streets. In testimony for this hearing, we also heard from both the Wyoming Department of Transportation and New York City Department of Transportation about their implementation of a USDOT pilot program that explores connected vehicle application concepts within limited, specific pilot sites for a finite duration. This allows the agencies to assess the impacts and evaluate the benefits. What are the pros and cons of taking what could be considered a more limited approach?*

Advocates' positions are all based on available research and data, which favors a controlled and cautious approach to the introduction of new technologies. This will be especially necessary as AVs are introduced, which is why we have called for a comprehensive regulatory framework that provides strong safeguards, government oversight and industry accountability. Public opinion polls have time and again illustrated overwhelming concern with the safety of AVs. This concern has grown after the recent fatal crashes of several Tesla vehicles and the fatal

pedestrian crash involving an Uber vehicle. The public absolutely should not be subject to beta testing of experimental technology on public streets.

As AVs continue to be developed, features such as emergency and warning functions can be introduced into vehicle fleets a way that will pose less of a threat to the public. That is why we support a requirement for automated emergency braking (AEB) in all vehicles. While the function of AEB is much the same as the braking function of an AV, in that it identifies an object in the vehicle's path and brakes the vehicle in response, the difference is that the AV can lull a user into overreliance because it takes over multiple aspects of the driving task. Whereas, the AEB system is only there to assist a human driver if they fail to respond appropriately at nearly the last moment before a collision is inevitable.

Additionally, connected vehicle technologies such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) can improve safety before AVs are fully deployed. For this reason, Advocates has supported the preliminary rulemaking from the NHTSA to mandate dedicated short range communications (DSRC) in vehicles.

Introducing these types of systems will allow for the collection and analysis of data to improve functionality while offering immediate safety benefits.

Senator Whitehouse:

8. *As our vehicles move towards automation, this change will require that our infrastructure and roadways are updated to ensure that autonomous vehicles operate safely and efficiently. Upgrades could include well-marked lanes, accurate signage, and traffic lights that can communicate easily and clearly with autonomous vehicles.*

    a. *What type of upgrades and investment should we be making now to our existing roadways and infrastructure to accommodate autonomous vehicles?*

The Federal Highway Administration (FHWA) should be directed to establish a new program to ensure collaboration among suppliers, manufacturers, test facilities, infrastructure owners and operators, engineers and safety consultants to develop research priorities to determine which improvements are critical to the implementation of connected and autonomous vehicles (AVs) while also benefiting human drivers. The agency must then be required to undertake this research and include identified necessary improvements in their priorities moving forward. Federal leadership will be necessary to research and execute improvements to aspects of infrastructure such as pavement marking, road design standards and signage. Moreover, leadership from the federal government to set standards for the safety and performance of AVs, and require relevant data recording and reporting, will be essential to set the baseline for the development of associated infrastructure needs. The limited funds available for infrastructure improvements necessitate that every federal dollar be spent wisely to avoid costly mistakes which can hinder the eventual benefits realized from the introduction of AVs.

    b. *Should we be making changes to our infrastructure and roadways with the intention that the vast majority of vehicles in the future will be autonomous?*

It is likely that we will be operating in a mixed-fleet environment for decades to come. For this reason, it is important that the needs of both human and computer driven vehicles are met. The linchpin for much of the guidance in numerous infrastructure manuals is a human behind the wheel. From sight distances for signs, to lettering, to the curvature and super elevations of roads, infrastructure design criteria has been developed to enable the safe operation of vehicles by human drivers. AVs will likely necessitate that these basic premises be modified to reflect the changing fleet on our roads. Research is needed to identify what infrastructure improvements, as part of a cohesive framework for AVs and overall safety, should be undertaken now to improve safety for both types of drivers.

c. *If electric vehicles make up the vast majority of autonomous vehicles, what type of infrastructure changes will we need to facilitate this transition?*

While these issues are generally outside of Advocates' mission and expertise, we are aware of discussions regarding AVs and vehicle electrification. One issue presented by the introduction of new vehicle types is ensuring that the support infrastructure (such as charging stations and qualified repair shops) is in place.

There are also safety concerns regarding recent high profile crashes involving electric AVs and the subsequent fires that result. Several of these fires have required extensive road closures, extended responses from emergency personnel and coordination with manufacturers to render the batteries safe after a collision. In a particular case, the battery in a crashed vehicle reignited days after the incident. The NTSB is currently investigating at least two crashes involving AVs where the battery malfunctioned as noted above. The Senate should not move forward with further consideration of the AV START Act until the NTSB finishes its work.

9. *Transportation is now the largest source of carbon emissions in the United States, and carbon emissions from cars and light trucks account for almost one-sixth of the nation's total emissions. We should be implementing policies in this sector with an eye towards reducing our emissions.*

    a. *How can we design the right policies so that autonomous vehicles that enter our roadways are fuel-efficient and help us reduce our transportation emissions?*

Fuel efficient vehicle design is outside of the mission and expertise of Advocates. However, we are aware that there are potential implications on overall fleet emissions levels associated with the introduction of AVs as discussed below.

b. *Do we know how autonomous vehicle adoption will affect overall traffic patterns and the number of miles driven by cars? If not, what is the best way to study and better understand this?*

Estimates of the impacts of AVs on traffic patterns and vehicle miles travelled (VMT) can vary widely. There are two starkly different scenarios projected. First is a utopia of a shared fleet of vehicles -- eliminating traffic and parking spaces to make room for green space. Conversely,

others envision a world of so-called "zombie AVs" circling the block endlessly mixed in with "hyper-commuters" working in their AVs during long trips to the office for a single meeting before working on the way back home again. While Advocates does not focus on research in this area, we are aware of studies that have shown the introduction of rideshare services like Uber and Lyft have had adverse impacts on traffic. The results of these studies may be indicative of the potential impact of the widespread use of AVs.

10. *Reports suggest that the autonomous vehicle industry could expand into the trucking industry, e-hailing, and ride-sharing industry.*

    a. *How soon can we expect widespread adoption of autonomous vehicles in these industries?*

Estimates regarding when AV technology will be used on a large scale vary greatly. In fact, a number of industry executives have themselves said that we are likely decades away. Advocates is unable to predict the rate at which adoption of AVs will be widespread. However, we do agree with assumptions that it is likely fleets (including trucks and rideshare services) will be early adopters. Though, until the technology is proven to perform safely, Advocates opposes the massive expansion of vehicles that may be exempt from federal motor vehicle safety standards (FMVSS), as contemplated by the AV START Act. Regardless, Advocates opposes any exemptions from the FMVSS which would reduce the levels of occupant protection afforded under the current requirements.

    b. *How can we get ahead of the potential job losses that could occur in traditional trucking and ride-sharing industries if autonomous vehicles are widely adopted?*

While these issues are outside of Advocates' mission and expertise, we are aware of discussions surrounding the impact of the introduction of AVs on the workforce.

    c. *Do we need to consider job retraining and workforce development policies to ensure that autonomous vehicle deployment does not disrupt the job markets for taxi, bus, and shuttle drivers?*

As noted, these issues are outside of Advocates' mission and expertise.

11. *Rhode Island's Department of Transportation, the City of Providence, and the Rhode Island Public Transit Authority are working on deploying an innovative transportation technology to connect Providence's Downtown to the Woonasquatucket River Corridor. The pilot will include a significant safety-testing component, to be completed prior to active use on city streets.*

    a. *Is it important that states and federal authorities do thorough testing through pilot programs to ensure pedestrian and driver safety? If so, how might these programs be structured? What duration and location of testing is appropriate?*

Advocates supports the thorough testing of new safety technologies. Such testing should be done in a controlled manner to minimize risks to the public. A combination of simulation and closed course testing would form the basis for justifying any public trials. Limited public trials with significant safety controls would be the next logical step for evaluating the technology and identifying issues and concerns. Finally, as safety performance data is gathered and verified, the conditions for testing would be expanded in a measured approach.

b. What kind of consumer education and awareness should be done in conjunction with further autonomous vehicle adoption?

Consumers must be given essential information about an AV. Every manufacturer should be required to provide each consumer with information about the capabilities, limitations and exemptions from safety standards for all vehicles sold in the U.S. at the time of sale as well as in the owner's manual.

NHTSA should also be required to establish a publicly-available AV database with basic safety information for consumers and for use in safety research. The database would be similar to the safercar.gov website that NHTSA maintains to inform the public about safety recalls applicable to their vehicle. The AV database would enable consumers to enter their VIN to obtain critical information about their AV such as the level of automation, any exemptions granted by NHTSA from the FMVSS, and the operational design domain which includes limitations and capabilities of each autonomous driving system with which a vehicle is equipped. Such a database will be critical for consumers who purchase AVs, especially used vehicles that are not required to have a consumer sticker (Monroney label) on the window and may be missing an owner's manual. According to Edmonds, there were 38.5 million used cars sold in 2016. The database would also allow NHTSA and other research groups to perform independent evaluation of the comparative safety performance of AV systems, and identify poorly performing and unsafe autonomous driving systems, as well as those that provide greater safety performance.

c. What are important safety components that a pilot program can include in order to facilitate the swift adoption of autonomous vehicles on our roadways?

Any pilot program involving AVs must be closely controlled in order to protect the public from becoming unwilling and unwitting test subjects. Effective pilot programs require careful planning from conception through data collection and finally analysis. An AV pilot program should have a set goal for evaluation, have a design for effective and appropriate data collection, a plan for analysis of that data to generate meaningful results, and above all, a safety plan to ensure that the public is not endangered and risk is minimized.

12. The introduction of autonomous vehicles in cities has the potential to add to congestion and idling emissions. What policies are necessary to ensure these vehicles serve to reduce congestion and emissions and instead increase affordable urban mobility?

This is outside of Advocates' mission and expertise. However, we are monitoring developments in this area and are aware of a recent study that has demonstrated ridesharing services have

increased congestion in some of America's largest cities. AVs share many of the same characteristics, and will likely be used as, ridesharing services.

Senator BARRASSO. Thanks so much to all of you for being here. I look forward to starting the questions in a second.

I do, first, ask unanimous consent to enter into the record a letter from the Alliance of Automobile Manufacturers, which explains the benefit of a development in eventual deployment of autonomous vehicles.

Without objection, that will be submitted.

[The referenced information was not received at time of print.]

Senator BARRASSO. Mr. Panos, as you discussed in your testimony, the Wyoming Department of Transportation is participating in the U.S. Department of Transportation study to assess the effectiveness of connected vehicle technologies really under real world conditions, because that is what this is all about. How has this effort helped WYDOT anticipate the changes that are going to be needed so that we can get the greatest benefit from connected vehicles and AV implementation?

Mr. PANOS. For us, the participation with USDOT and with our partners on the project is really a benefit to us because our focus is on safety, and the idea that we have the ability to deploy technology in a variety of different environments. As you know, the pilot study is not just about Wyoming, but it is also inclusive of New York City, the New York area, and also Florida; and working in these kinds of deployments and these kinds of environments is extremely beneficial to studying the effectiveness of the technology and the various conditions within which it is going to have to operate, so that is very, very important.

As I described both in my written and oral testimony, we have already started to deploy not only the technology within our own fleet, but with freight vehicles as we move forward, so I think that the ongoing funding by USDOT, ongoing funding by the Federal Highway Administration toward going to Phase 2, Phase 3, toward further deployment of these technologies is critical for us to improve safety.

In our particular case, we have a great deal of freight that moves through the southern part of our State, and our focus is on not only maintaining a safe environment for that freight to move, fewer fatalities, fewer crashes, et cetera, but fewer closures of that road system so that freight can move from the western side of the country to the eastern side of the country and vice versa.

So, for us, these connected vehicle programs are an initial step toward connected braking and then automated vehicle programs which are necessary to save lives.

Senator BARRASSO. In addition to the study that you are actually involved in, are there any further efforts or follow up activities that we ought to be thinking about or pursuing to get more information?

Mr. PANOS. Yes. I think that FHWA recently announced a series of national meetings to discuss automated vehicles and infrastructure. Congress can encourage the FHWA to move forward promptly on those meetings.

AASHTO has been working hard to bring people together for years and has updated its coalition of public and private sector entities to form the Cooperative Automated Transportation Coalition, or CAT Coalition. Those types of efforts should be encouraged.

They will help bridge some of the current gaps in the collaboration among all of the various stakeholders.

Senator BARRASSO. Mr. Bhatt, everybody has testified to this. In order to successfully prepare our roadways for autonomous vehicles, State and Federal agencies are going to need to engage in proactive preparation, rather than just simply reacting. What do you perceive as kind of the primary regulatory challenges or opportunities that are going to determine the infrastructure and agency readiness as the use is adopted and expanded for autonomous vehicles?

Mr. BHATT. Thank you, Chairman, for that question. It is a great question to ask right now because I think that what you hear in the testimony across this panel is there is both great opportunity and great challenges that we need to understand, and I think it is a great time for this Committee, Congress as a whole, and the Administration to be looking at these issues.

From a regulatory standpoint, I think what we need right now is a Federal framework so that we don't have 50 different States and then along with other cities and jurisdictions sort of developing their own standards when it comes to the operation of these vehicles. I think that that is one of the things that we are looking for.

I also think it would be important for us to recognize that this is not just about the United States; that there is a global competition around both vehicle manufacturing and communication technologies where other countries are investing and actually cite the fact that there is no consistency across the United States as a competitive advantage for companies to come and manufacture and test in those places.

So, I think that what we want to make sure is that we preserve the historic, that we have had for several decades, relationship of manufacturers make the vehicles and then local jurisdictions decide how they are operated, but we need a Federal framework to make that happen.

Senator BARRASSO. Thank you very much.

I have a lot more questions, but Senator Rounds, let me go to you first.

Senator ROUNDS. Thank you, Mr. Chairman.

As I listened to the discussion here, I noted that we have folks from New York, Wyoming, Colorado, and when I think about the differences between the way each of your different transportation commissions would respond to what your needs are, and I am not certain that, at the Federal level, we can determine for all of them what they need to do and the priority in which they need to do it.

At the same time, I guess I am going to ask the loaded question, and that is with regard to the Highway Trust Fund. Is there anybody that thinks that we should have a subsection dedicated to the advancements of these particular capabilities within the Highway Trust Fund? Remembering that you are probably taking money away from bridges and road repair, road construction, and so forth. Where do you put this at?

Yes, sir.

Mr. BHATT. I am happy to take the loaded question, and I appreciate your perspective that it is a very different country, whether

it is New York City or Wyoming, Colorado, or Washington, DC. And I appreciate the idea that we recognize that.

I think that from the ITS America perspective, which is a coalition of State DOTs, cities, private sector companies, and research institutions, I think, with regard to the Highway Trust Fund, recognizing the challenges that are there, it is hard to say, well, how do you fund important technology investments, and at the same time, many States are struggling with this idea of we can't maintain the existing roads and bridges that we have.

So, I would say that our association would say, along with, I think, a broad bipartisan chorus, that there does need to be more funding available for transportation, but I think that what I would focus on is the ability of technology to leverage existing investments.

We all talked about pavement markings. Striping is a big deal obviously for the performance of autonomous vehicles. In Colorado we had the Eisenhower-Johnson Tunnel, the highest interstate tunnel in the country, and snow can fall there virtually any time of the year. Those plows go out, and a stripe is just really paint on asphalt. You plow it enough times, it comes off. What they have deployed in Colorado now is almost like a recess within an LED light inside it, so when that plow goes over it, it doesn't scrape away paint, it doesn't scrape away anything, and it is a much safer piece of infrastructure.

And the next step of technology is—I have talked to companies that want to put a little RFID chip in there so that that RFID chip can broadcast to a plow that I am here, so if you can't see the roadway, that you at least understand where the lane is.

So, whether it is signals through the SPaT Challenge that can be upgraded, I think that there are many ways that we can see that technology can leverage the existing investment. We currently use 2,000 vehicles per lane per hour for what a lane of interstate will move. Once those vehicles are talking to each other, you can cut down on stopping distance. I have seen estimates where that can go to 4,000 or even higher. So, I think we want to begin the conversation around how do we use investment to leverage both the existing infrastructure and the technology investment.

Senator ROUNDS. Interesting. I am just curious. I look at the different weather conditions that are out there right now, and my first thought was is perhaps the first step would be to provide more information to both drivers and driverless vehicles, and a lot of that data could be used by both, as opposed to simply focusing on the autonomous vehicles.

You mentioned snow. I am thinking of the percentage of the time in which our rural highways and places like in South Dakota, where I am from, where we are not going to have the visibility of stripes, we are not necessarily going to have the visibility of a yellow line down the road, and those are the times in which these accidents, in many cases, occur, adverse weather conditions.

Then I look at New York, and I recognize the expertise of your taxi crew there to actually work its way down through a 5th Avenue challenge is something else, and it is something that very few of us in South Dakota get an opportunity to experience, nor want to experience.

So, it would appear to me that what we can do to provide additional data is something that would help everyone, including, and I suspect as Mr. Kildare had indicated, the ability here to provide additional information that is actually beneficial to both the driver and a non-driven vehicle. I am wondering if the focus perhaps shouldn't be more, to start out with, making sure that we have the ability to deliver ongoing data, such as with a stop sign that could be modified. But if you have a GPS that indicates clearly that there is a stop sign expected at that location, to at least show if there is a difference between what is perceived with the visible perception versus what the GPS should be there would throw out the proverbial red flag.

And then I will shut up.

Would you agree with that, Mr. Kildare?

Ms. TROTTENBERG. I would certainly jump in. From the New York perspective, that data is key. And as you heard from my colleague in Wyoming, New York is also participating in the Connected Vehicle Pilot, and the information that we are gathering is going to be very, very crucial.

That is why we think it is important, as automated vehicle testing goes forward, that jurisdictions, cities and States, that we work out some kind of data sharing arrangement, because that data will be crucial to us in making some of these infrastructure decisions and seeing where there are safety challenges, places we need to improve the efficiency of our roadways.

You know, you are talking about, in a rural context, snow covering up your markings, in an urban context, particularly in a city like New York, we have a ton of infrastructure underneath our streets. On any given day in New York City there are a thousand holes being cut into our streets, so the notion that our striping will always be pristine and visible, I think it is not likely.

Senator ROUNDS. Or parked on.

Ms. TROTTENBERG. Exactly.

Senator ROUNDS. Thank you.

Thank you, Mr. Chairman.

Senator BARRASSO. Well, thank you very much, Senator Rounds.

Senator Carper.

OPENING STATEMENT OF HON. THOMAS R. CARPER, U.S. SENATOR FROM THE STATE OF DELAWARE

Senator CARPER. Thanks much, Mr. Chairman.

Welcome to all of our witnesses, especially Shailen Bhatt, who used to be our secretary.

Shailen, it is great to see you, and thanks for bring your friends with you here today.

I apologize for being late. We all serve on a number of committees, and sometimes we just bounce back and forth easily, but we are doing a markup, a business meeting in the Homeland Security Committee today with a big agenda, and we had exactly a quorum; and if I had left, we would have lost the quorum and not been able to proceed, so I appreciate your indulgence here.

I have a short statement I would like to share with all of you.

This important hearing, we are grateful for it, Mr. Chairman. I thank our staffs for the work that has gone into preparing for it.

Harry Truman used to say the only thing new in the world is the history forgot or never learned. Think about that. The only thing new in the world is the history we forgot or never learned.

Today we are here to discuss autonomous vehicles, which do seem like a very new thing, but over 100 years ago, before the advent of driverless cars, the new thing was the horseless carriage, or as we now call them, cars.

Reflecting on the early history of cars and automobiles, trucks, reflecting on that early history may provide some lessons as we plan for the deployment of today's new technology. I doubt there is anyone here who would deny the tremendous benefits of the development of cars, trucks, vans has had on our society and our economy.

These vehicles connect urban and rural communities; they provide new access to schools, to jobs and hospitals. Cars and trucks have allowed us to travel farther, and to ship and receive goods more quickly and more cheaply.

It is also fair to acknowledge that these mobility improvements have come with some costs. We had to make space in urban areas, often at the expense of existing housing, for better infrastructure in the form of roads and highways. Think I–95 going through Wilmington, for example. Motor vehicles quickly became a major source of emissions and smog, contributing to the threat of climate change, as well as public health crises, such as asthma.

The advent of early automobiles also posed a major safety challenge, and infrastructure was required to ensure that they operated more safely. I am told in the first decade of the 20th century there were no stop signs; there were no warning signs; there were no traffic lights; there were no lane lines; there were no streetlights; there were no brake lights; there were no driver's licenses; no seatbelts; no posted speed limits. None of these traffic controls and safety devices had been developed, so communities were unprepared for this new technology, new vehicles that came along about 100 years ago.

As a result, passengers were at risk. I am told, in 1910—more than 100 years ago—there were 45 deaths for every 100 million miles traveled. Forty-five deaths for every 100 million miles traveled. We have been able to bring that number down to a number just about 1 death per 100 million miles traveled today thanks to a variety of things, but thanks in part to Federal motor vehicle safety standards and investments in safer roadways and safer vehicles.

I think most of us would agree that the number even one, if you happen to be that one, that is one too many. The number is still too high, but in 2016 I am told almost 40,000 people were killed in crashes on our roads across this country.

I hope that autonomous vehicles will help us reduce fatality rates even further. Over 90 percent of traffic fatalities are the result of driver related errors, including from drunk, drowsy, or distracted driving. They may be reduced with driverless cars. That would be a good thing.

Indeed, there is no doubt that this emerging technology has the potential to enhance safety, to enhance mobility, reduce congestion, and improve excess. But realizing these benefits will depend on two

important things: No. 1, how the technology is deployed, and also how much we invest to ensure that our streets are ready for this new technology.

One of our major goals should be to avoid the mistakes of the last century, when cars were deployed into our communities without any of the infrastructure standards, the traffic devices, the safety protocols, the environmental protections that we only later realized were essential.

Our hearing today will help us better understand how we can prepare for this transformative technology so that we can realize its many potential benefits, but also minimize the costs associated with cutting corners in our zeal to see this exciting technology deployed.

We need to better understand the readiness of our infrastructure and our traffic controls. For instance, we know that autonomous vehicles can have difficulty navigating certain road conditions, such as poor lighting, such as bad weather, such as work zones. So how do we mitigate with these challenges?

Connected autonomous vehicles may travel more closely together, which could reduce congestion. That would be a good thing. But how will a connected series of heavy trucks affect the weight limits of highway bridges? That could be a dangerous thing.

Road designs and traffic signs have been optimized for human comprehension; however, we look at the very simple changes that can be made to a stop sign that could interfere with an autonomous vehicle's ability to accurately understand that same sign. I think we have a poster. If you look at the stop sign, with just a couple markings that could be made to the stop sign, it turns into not a stop sign, but a speed limit that says you can go 45 miles per hour through this intersection. That would be scary.

So, we need to ensure that vehicle computers will read signs like that, particularly when graffiti or other modifications can fool an autonomous vehicle into thinking that a stop sign is actually a speed limit sign. We all know, as much as we might hope that something like that is not going to happen, we know that it very well could.

We may need to digitally connect our vehicles to our infrastructure. How much will that cost? How do we ensure that it is compatible with all autonomous vehicle technologies?

Finally, technology is changing at a rapid pace, we know that, but State and local agencies must plan now for transportation investments that won't be made until much further down the road.

How do we align those timeframes and integrate assumptions about autonomous vehicles into long range transportation plans?

Those are just a few of the many questions that I believe we need to be examining closely as we prepare our infrastructure for more widespread use of autonomous vehicles.

I look forward to your testimony. Apologize again for being late, but better late than not at all. Now I am here, and I am in the game.

Thanks so much, Mr. Chairman.

Senator BARRASSO. Would you like to proceed with questions, or should I go to Senator Capito?

Senator CARPER. I would go to Senator Capito.

Senator BARRASSO. Senator Capito.

Senator CAPITO. Thank you. Thank you, Mr. Chairman.

And I thank all of you.

Mr. Panos, like West Virginia, Wyoming is a largely rural State with difficult and mountainous terrain. Whenever I hear and think about autonomous vehicles, I think about going up Bridge Road, which is where I live, to my house, and I am like, I am not getting in an autonomous vehicle and doing those curves.

We also have difficulty with in and out of our service, satellite service or Internet service. It is very spotty and can be unreliable. In the best case unreliable, and in the worst case, non-existent.

I understand that in Wyoming your testing is usually in ideal weathers and more flat circumstances, but you are doing some testing in the mountainous regions, so I am interested in knowing how that is going and what type of challenges that presents in terms of autonomous vehicles.

Mr. PANOS. Thank you for the question. In Wyoming we are testing not only in open areas, but also in mountainous areas. We have a very diverse terrain. We also have very diverse weather conditions. So, we are testing the infrastructure equipment not only for its ability to speak with vehicles and for vehicles to speak with it, if you will, but also to test it in terms of its nature as it relates to the various geologic and weather sort of conditions that we have there.

What we have found is, for us, we use DRC-enabled equipment that helps in our communicating with the vehicles. Our focus is on connected vehicles at this point, and connected freight vehicles, specifically.

Senator CAPITO. So, when you are saying connected, are you saying connected to the device that is on the infrastructure, or are you talking about connected in a broadband, wireless way?

Mr. PANOS. Well, to use your examples, both.

Senator CAPITO. Both.

Mr. PANOS. They are connected vehicle to vehicle and then vehicle to infrastructure. And then the infrastructure is connected back to a central location where we actually can send messages to those vehicles——

Senator CAPITO. So you have to have connectivity.

Mr. PANOS [continuing]. And transmit them to others. Excuse me; I apologize. And DSRC helps us to do that, but I think that what we believe will be enhanced is not just the type of technology that we use, because we could use a variety of technology, but really the type of messages and advisories that we are pushing. Advisories about crashes, advisories about weather that are up in front are the most effective that we can see.

But I must say that this idea of developing a collaboration amongst all of the stakeholders associated with the type and use of technology, whether it be connected vehicle or autonomous vehicle, is the key, and these collaborations, and having Congress support those collaborations, is essential for us as we go forward not just as Wyoming, but as all State DOTs.

Senator CAPITO. I am also serving on the Commerce Committee. We had a very vigorous debate on AV technology and cars and trucks, and should trucks be included in the first sort of strike that

we went in terms of trying to figure out the best regulatory environment to move forward. Trucks were not made a part of that.

I am wondering if any of you all, in your testing or exposure, has been working with large truck vehicles and what you are finding there.

Mr. PANOS. I will just mention, if I may, Senator, that that is the focus of our connected vehicle program, is freight specifically, and freight connected not only to the infrastructure and to one another, but freight connected to our emergency response vehicles so that we can reduce the time that an emergency responder can arrive to the scene of an accident or some other type of incident.

Senator CAPITO. OK.

Mr. BHATT. Senator, obviously, the freight component is critical.

Senator CAPITO. Right.

Mr. BHATT. One of our members is Peloton that is testing truck platooning, where you use connection between vehicles to reduce the space that is needed, reduce the fuel economy. In places like Wyoming and in Colorado, where you have long distances, it can provide a lot of benefit, safety benefits.

Another issue in Colorado, over Red Mountain Pass, we sometimes have truckers coming into the State that have never been there. There is an issue on I–25. Now they are using their GPS to get around it; they end up on Red Mountain Pass, and Red Mountain Pass there are a couple of curves where, if you don't negotiate them properly, it turns into a pretty significant situation. We are looking at deploying infrastructure to vehicle communication so that even if the truck driver isn't aware that it is a safety issue, the truck can be told to slow down to no more than 10 or 15 miles an hour for some of these curves.

Senator CAPITO. Interesting. Thank you very much.

Senator BARRASSO. Thank you, Senator Capito.

Senator Carper.

Senator CARPER. Did you go to Ben?

Senator BARRASSO. Well, it is your choice. You are first to go with questions, but Senator Cardin would be next in line.

Senator CARDIN. Well, thank you. Thank you, Mr. Chairman, and thank you, Senator Carper.

This hearing is extremely important, and I thank all of our witnesses.

I have the opportunity to be the Ranking Democrat on the Infrastructure Subcommittee with Senator Inhofe, and as we are looking at the infrastructure authorization for America on transportation, clearly the technology issues need to be part of those conversations, so I think this panel is particularly important. We all support the enhanced use of technology to make transportation more efficient, to make it more friendly, to make it safer.

Certain challenges are brought out by this, and you have already mentioned some. How this comes out of the maintenance budget I thought was an interesting concept, as compared to construction. We don't have enough resources right now into the transportation, so unless we have an adequate funding source, it seems to me that technology is not going to get the attention it needs in the planning of infrastructure.

Second, I would point out that technology will help make transportation more efficient, which is what we want it to be, more efficient. But as we make it more efficient, the revenues that are coming in to support the infrastructure gets lower, gets less. So, once again, it is so important as we look at developing an infrastructure program for this country, that we take technology into consideration so that we have adequate resources in order to take advantage of the benefits of technology.

I want to talk about a couple specific issues. I was listening to the messaging boards that you talk about. Very important. If there is a serious issue, motorists need to be advised so they can plan alternative routes, they can plan safety decisionmaking.

But I find that many of these messaging systems are putting up messages that are not terribly relevant to the driver, but do cause the drivers to slow down, causing congestion and sometimes a safety problem in and of itself.

Is there a protocol as to how these messaging boards are located and whether they should be used indiscriminately or when it is not involving an important message for the driving public?

Mr. PANOS. Senator, could I respond to that? Thank you for the question. There is a protocol, actually, that we have developed with the Federal Highway Administration for the siting, construction, and operation of DMS signs, digital messaging signs, throughout our State, and we have internal groups which actually look at the messaging that is going up, plus we have a 24/7 online traffic management center that actually executes the messages to the signs and makes them as real time as possible. So, for instance, if we were to have a hail incident that would move through or actually blow through the State from, let's say, west to east, the message signs would change and follow the hail incident as it moves across the interstate highway warning——

Senator CARDIN. And that is beneficial. I am for that. But my concern, I will look at my app as to traffic problems on I–95 as I am driving, and I will see either yellow or red where the messaging signs are located, and I know the people are slowing down in order to read the messaging signs. Fine if it is important, but if it is not—some of the signs will say have a happy holiday weekend, drive safely, or something like that, which I don't think is worthy of creating a particular problem of a slowdown because people are slowing to read the message signs.

Mr. PANOS. Senator, if I may, again, we have a protocol so that we generally would not be putting up non-relevant information on the signs relative to that particular area of the State. Remember, I–80 in our State, where there are a lot of these DMSes, is 400 miles long, so we would put different messages, but also safety messages; and those are the only two things we are allowed to put on the signs based on the protocols that at least we use in Wyoming.

Senator CARDIN. Appreciate it.

I want to cover one other subject, if I might, and that is vulnerable populations, bikers, pedestrians. As we develop these new technologies, what protections are there for what this Committee has brought forward under the TAP program to promote pedestrian

and bicycle opportunities? If you are now going to have automatic technologies, how do we protect the bikers and walkers?

Ms. TROTTENBERG. I will take a crack at that, Senator, because I think from the New York City context that is an extremely important question. For our Federal pilot, the Connected Vehicles program, that is one of the issues we are very much looking at; it is not just vehicles talking to infrastructure, it is how can we make roadway safety better for pedestrians, for cyclists. That is part of why we are so interested in having some robust safety protocols as we start the testing. Europe is looking at requiring certain pedestrian and cyclist recognition technologies and why we are interested in having good data sharing, so we can learn what these vehicles are seeing. For us in New York, pedestrian and cyclist safety is a huge, huge priority.

Mr. KILDARE. Thank you very much for the opportunity to respond. I think we saw the dangers writ large by what happened with Uber and the crash that occurred. There was mention earlier about edge cases. The problems we are seeing with AVs at this time are not edge cases. A pedestrian crossing a road at night is not a surprise. A fire truck being stopped on a road is not a surprise. A tractor trailer making a left turn across traffic is not a surprise. These aren't edge cases.

So, we need to collect a lot more of that data. We can do that during testing in controlled ways, but without allowing the system to put people in danger. You can run these systems with a human driver actually doing the driving, collect the data streams, analyze it, and see what they are seeing. If we see that the machine would have made the decision to drive toward a bicyclist, we would know that without actually endangering the bicyclist and letting the machine drive toward that bicyclist.

The same thing we saw about the infrastructure problem, what happened with the latest Tesla crash. We would have the data stream saying, hey, the vehicle would have liked to have driven into this roadside hardware, but it didn't because the human driver was always engaged and always doing the driving. So that data is absolutely crucial to collect and have.

Senator CARDIN. Thank you all very much. Appreciate it.

Senator BARRASSO. Thank you, Senator Cardin.

Senator Booker.

Senator BOOKER. Thank you very much, Mr. Chairman.

I have a lot of concerns about just the rising levels of traffic fatalities on our roads. It is stunning to me that we have this kind of carnage. 37,461 people were killed on our Nation's roads in 2016 alone. And we seem to have—maybe popularly—seem to have this resignation that this is just a normal, and it shouldn't be. You know, when you see lives devastated like we have seen in New Jersey very recently, especially with the horrible crash involving a school bus, I think we have to start having more of a conviction to prevent these tragedies from happening.

So emerging sorts of technology is hopeful to me, that there might be a lot of possibilities. Autonomous vehicles present, to me, first and foremost, a chance not to ease congestion; the biggest thing that excites me is the potential to save lives. There are other collateral benefits, reducing emissions. If you live between New

York and New Jersey, one side of the river or the other, you understand how traffic is eroding the quality of life of people.

So, I just want to make sure that we are making the kind of investments in our infrastructure that we should be making, and I want to start with Mr. Kildare, which is the greatest name, man, you have, by the way. If I had that name, I would have made it to the NFL in football. The name alone would have gotten me through the combines.

Senator BARRASSO. Or he could have been a doctor on television.

Senator BOOKER. Exactly. Exactly.

America's roads continue to receive a D from the ASCE, which noted that 20 percent of the Nation's highways alone had poor pavement conditions. The Federal Highway Administration estimates that $142 billion in capital investment would be needed on an annual basis over the next 20 years to get our conditions to where they should be.

What is, again, compelling me is that, tragically, approximately one-third of road fatalities are caused in part due to deficient infrastructure.

The first question, Mr. Kildare, is whether it is State DOTs, local governments, transit agencies, the whole list of sort of multiple crisscrossing responsibilities, the transportation sector is going to continue to wrestle about how to deal with the new technologies that we are seeing and integrate them in an effective way, and to make this, capital investments are going to be needed in order to accommodate connected and autonomous vehicles, cars, buses, trucks, and the like.

So, I just want to know what would you recommend in terms of the investment that you think Congress needs not only to accommodate the issues I am talking about, but even just to compete globally to other nations that seem to be making infrastructure investments much more rapidly than we are.

Mr. KILDARE. I believe that the Federal coordination is going to be a critical part to this. A lot of our manuals and a lot of the instruction that we currently have of how we spend our funds and what our designs are are left to the local level, and that is important. It is important because we have the difference between rural and urban and the different experiences that we have.

However, things are going to change as we bring in autonomous vehicles. A tractor trailer trying to find a lane line in Wyoming is the same as the system that is trying to find a lane line in New York City; it needs to know that that is a lane line. You can travel from place to place and see that lanes here are 12 foot wide; this one is 8 foot wide. Lines are 10 foot; they are 15 foot. Everything starts to change because we have allowed this engineering judgment. And it has been critical up to this point, but it is also because they were critical to have the engineering judgment to change based on your area.

When we start having autonomous vehicles, it starts to level that playing field. Finding the right technology and working together so that we know what is the best way we can get each car to know that that is a lane line. What is the best way to get each car to know what stop signs are and not have the confusion that we saw from the stop signs that Senator Carper had put up? How do we

get everyone organized on that so we are making the best investment, especially considering that we need to do both for a long time?

We foresee for a long time coming we are going to have both human drivers and autonomous vehicles, and the last thing we want to do is spend our money heading toward fixing one problem and then creating problems for the other.

Senator BOOKER. I appreciate that.

I want to turn in the seconds I have left, and I see Senator Markey has come, to the DOT Commissioner for—I am sorry, which city is that again?

[Laughter.]

Senator BOOKER. It sits in the shadow of Newark, New Jersey; I understand that.

[Laughter.]

Senator BOOKER. It is tough. It is tough. You and Senator Schumer have city envy, I understand.

Senator Cardin asked the question about the challenges as this technology comes in, and the excitement for me about our metropolitan area is tons of new technology could really ease what is an infrastructure crisis that we have in our region. So, I wonder if everything from AVs to, frankly, just drones alone could take a lot of the traffic off of our streets, and in places like New York City, drone technologies might be sort of a possible help.

I said this to the head of the FAA for a while, I said, look, they were choking sort of the ability for localities to experiment with new technologies, and I felt, overregulating them. France, for example, is doing so much more on drones than we were doing because they had better regulatory structure. And I said, if you guys were around during the time of Wilbur and Orville Wright, we would have never gotten off the ground.

So, I am just wondering, as this person that understands the critical crisis we have. I live 12 miles, 11 miles from Manhattan, and it can take me upwards of 2 hours to traverse that. New Jersey transit, and again, all the work I have been doing on the rail tunnels.

We are just in a crisis proportion. So how are you feeling in the ability to sort of embrace innovation, to create sandboxes for different technologies that you think are critical? And are there things that we can learn from your experiences in one of the most congest metropolitan areas on the planet Earth, the greater Newark metropolitan area?

Ms. TROTTENBERG. It is great to be in the greater Newark area.

You are right, Senator, congestion for us in the entire metropolitan region is a huge, huge challenge. The potential of AVs is that they can reduce congestion, but I can just say right now, I think the New York City experience—and it is probably true across the river, we are finding services like Uber and Lyft, which say they will eventually be a ridesharing system, right now they are just adding more cars to our streets.

Senator BOOKER. Yes.

Ms. TROTTENBERG. And in midtown Manhattan, travel speeds are really slowing, and it is a real challenge. I am actually fortunate right now to be chairing Transcom, which is actually a coali-

tion of New York, New Jersey, and Connecticut transportation and enforcement officials. It was actually the group that got Easy Pass started throughout the region. And we are actually trying, as a region, to look at some of what are these next generations of technologies and bridge one of the challenges we all face, which is how do we bring all our jurisdictions together, New York, New Jersey, the Port Authority, the MTA, New Jersey Transit. Because there is both the technology piece and the jurisdictional and governance piece in making sure, to the extent that we are all pursuing these technologies, they can talk to each other and we can work together.

Drones I think, for New York City, our airspace is pretty dense. I don't know if we are ready to go there, but we are, as we have said here today, doing connected vehicles and starting to look at, again, things we could deploy regionally, because we are one region.

Senator BOOKER. Yes.

And just a question for the record: Where do the Jets and the Giants play?

Ms. TROTTENBERG. In the region.

[Laughter.]

Senator BARRASSO. Case closed.

Senator Markey.

Senator MARKEY. Thank you, Mr. Chairman, once again.

Once again, this is an area where Senator Booker and I compete. We compete. I just had him check it out. New York has the second worse congestion and we are No. 7 in congestion, Boston. One place where we would like to be behind New York in this one category, maybe the only category. And Washington, DC, is No. 6.

So, between New York, Boston, and Washington, we have a lot of reason to solve this problem. It is consuming a large percentage of the discretionary time that we have left on the planet, just sitting in vehicles and waiting to get to places, and this new revolution is really computers on wheels, just going down the street. And these computers on wheels could soon be able to send speed and direction data to other vehicles, roads, bridges, other transportation infrastructure, to improve safety, reduce traffic, improve efficiency.

In the very near future we may be spending Federal highway funds to embed sophisticated sensors into our roads and our bridges, and like the everyday computer and smartphones, these transportation technologies could be vulnerable to cyberattacks if appropriate safeguards are not put in place up front.

Just a few years ago hackers remotely took control of the brakes, steering, and acceleration of a Jeep Cherokee. Chrysler had to recall 1.7 million vehicles to fix this cybersecurity problem. If we are to imagine a world where massive 18-wheelers carrying hazardous materials and minivans full of children can drive themselves, it shouldn't be a stretch of the imagination to envision that these vehicles may be targets of cyberattacks. And unlike many technologies that are already deployed, we have the unique opportunity to address cybersecurity threats before they emerge.

Mr. Kildare, do you believe that we should proactively ensure that robust cybersecurity protections are built into the design, construction, and operation of these transportation technologies?

Mr. KILDARE. Absolutely. It is a significant concern. It is also a big concern that we have about the pending legislation, the AV START Act, is that there is no consideration for requirements. I believe the only thing that is in there is a recommendation that companies have a game plan, but not necessarily executed or follow any standards that are available. We have great examples of how this can be done in lots of other industries. We need to start taking those and learning those lessons from history about how we make these things secure.

Senator MARKEY. Beautiful. I agree with that, and that is why I have introduced legislation with Senator Blumenthal, the SPY Car Act, that directs NHTSA to establish Federal standards to secure our cars.

Mr. Kildare, do you believe that it would be helpful if NHTSA, the National Highway Traffic Safety Administration, created a cybersecurity certification program for vehicles, similar to NHTSA's five-star automobile safety rating program? The program would reward manufacturers who adopt the strongest protections, while also helping consumers make more informed decisions when purchasing or riding in vehicles.

Mr. KILDARE. Absolutely. I believe the benefits that we have seen from the NHTSA five-star program have shown how we can encourage competition in the goal of getting safety out the forefront. The same thing can be done with the cyber dashboard and looking at cybersecurity. We always want to see it move toward regulation at the end, and we have seen that happen out of the five-star program as well, so it is an excellent goal.

Senator MARKEY. Now consumers say, oh, how many miles per gallon? We can see that. What is the safety rating? They can see that. And going forward, this cybersecurity protection is also going to be increasingly important because it is a computer riding down the street, and there is a sinister side to cyberspace. It is the best of technologies and the worst of technologies simultaneously. There is a Dickensian quality to it; it can enable, it can ennoble, it can degrade, it can debase. We just saw that in the Facebook hearing. We continue to see it. If we don't protect against the downside, then bad things happen, so it is important for us to build in the cybersecurity protections now.

Finally, the only thing more quintessentially Boston than cold weather and the Boston Red Sox is traffic. But technology could help address traffic issues by allowing communities to more accurately and comprehensively monitor traffic patterns and then take preventative measures—rather than reactionary measures—to alleviate congestion.

How can these sophisticated transportation technologies help us be more efficiently traveling, especially in the densely populated urban areas of the country?

Ms. TROTTENBERG. I guess I will speak for densely populated urban areas. I think, again, sort of speaking of the Dickensian nature of these potential technologies, as you have heard, they can potentially enable vehicles to travel together more closely, to anticipate obstacles in the roadways, reduce crashes and accidents, which obviously has a big effect on moving traffic.

I think it is certainly true in the metropolitan region of New York, and Boston as well. I just have to sort of have to make a pitch, I guess, for a different committee's jurisdiction. For us in the end, the biggest thing that is going to help us probably solve our congestion problems is going to also be robust investments in our mass transit system. The efficiency of what a train can carry, even versus a platooning set of vehicles, there is no comparison; the mass transit system is always going to be the workhorse for New York in terms of carrying the population.

Senator MARKEY. Thank you, Mr. Chairman.

Senator BARRASSO. Thank you, Senator Markey.

I was just talking with the good Senator about he was too young to remember the doctor show that we grew up with, Dr. Kildare.

Senator CARPER. Dr. Kildare, Ben Casey, Dr. Casey. There were a bunch of them.

Senator BARRASSO. There was Ben Casey, there was Dr. Kildare, there was Marcus Welby, MD. That is why I became a doctor.

[Laughter.]

Senator MARKEY. If I may add, that is why my wife became a doctor, looking at Dr. Kildare. And the beginning of the show is the front of Massachusetts General Hospital in Boston, Massachusetts. All politics are local.

[Laughter.]

Senator MARKEY. The inspiration came out of that location.

Thank you.

Senator CARPER. I know his wife. My wife and I are good friends, and his wife is an inspiration.

The Chairman and I were talking just a little bit. I have some prepared questions, but one that is just an audible here, he represents a big State and a lot of roads, and a lot of those roads in his State are dirt roads or gravel roads.

As Chairman Bhatt may recall as Secretary of Transportation in Delaware, we used to have a whole lot of dirt roads and gravel roads. We don't have quite as many anymore, but we have a lot of roads in the more rural parts of our State that are not marked. We still have some dirt roads and some gravel roads, but there are a lot of places across the country that are more like—not just the town of Wyoming, Delaware, but are more like the State of Wyoming, where they have a lot of dirt roads and gravel roads.

How do we handle that? How do we stripe them and get ready for just minor, inexpensive infrastructure enhancements that will help make autonomous vehicles work in those areas? How does that work?

Mr. BHATT. So, that is a great point to make, Senator Carper, and a great question. One of the things that I know Colorado DOT is taking a look at as a research program now, working with other partners, SAE classifies autonomous vehicles Level 1 through 5 based on their ability to either be driven or self-driven.

What Colorado DOT has begun looking at, or the RoadX program, is a roadway classification system. So, we will have interstates that have great pavement and markings and signage and connectivity, all the way down to a rural dirt road that may not even have cellular coverage. Much like when you used to buy a cellphone, you were provided a map around where that cellphone

could work, I think there will be part of our network that will never have those levels of connectivity, and it will be up to, as Commissioner Trottenberg said, the manufacturers to make sure that their vehicles are able to drive on a vast majority of our system.

Senator CARPER. But as we all know, there are a lot of times when we go around States around the country, we try to use our cellphones, and they don't work. I know a lot of people with autonomous vehicles say, well, I will take a chance; maybe it will work today.

All right, thank you. That is interesting.

OK, a question, if I could, for Polly Trottenberg.

How are you today? Very nice to see you.

Have auto manufacturers and software developers shared information with you about their technologies' reliance on infrastructure in order to safely navigate public roads? This information seems like it would be vital to the public agencies who own and operate our transportation infrastructure when setting standards and shaping the deployment of autonomous vehicles to ensure both safety and compatibility.

I guess specifically do you think that access to safety evaluation reports would better equip our public agencies in their efforts to set appropriate standards for autonomous vehicles?

Ms. TROTTENBERG. Absolutely, Senator. We think that is crucial. I think Mr. Kildare put it well.

Senator CARPER. Dr. Kildare.

Ms. TROTTENBERG. Dr. Kildare. It is essential for us, as he was saying, as these vehicles hit the roads and start doing their testing, to know where they had near misses, where they might have interacted with a pedestrian or cyclist. It is important for us to get the sense of their safety operations, but again, it will help us as well, it will help us look at our infrastructure. It is really valuable data.

Certainly, I think something to be very thoughtful of as you are regulating at the Federal level and at the State level, for a city like New York, which is such a big and unique entity in and of itself, we really want to make sure that we have a seat at the table and that we can be part of understanding that data and very sensitive to protecting it and the proprietary nature of it. But it is really key for us, in our dense urban environment, to understand how these safety systems work and what they are seeing if they hit our roadways.

Mr. DOERZAPH. I will add a little to that, too. One of the neat things about these new vehicles is they come with a plethora of sensors that provide very direct information about what it is in the infrastructure that creates a difficulty for them, which can help an operator really prioritize how they spend those public dollars by focusing on the elements. It may be as simple as a reflection off of a particular bridge that radar over-responds to. So, having not just general feedback to where incidents are, but details about what it is that is fouling up a particular sensing or perception system is new and also potentially very valuable.

Senator CARPER. All right, thank you.

Mr. Panos, you have been before us before; so has Shailen, as have one or two others before us today. Are you a director of the Department of Transportation? Is it director, secretary, commissioner? What is it?

Mr. PANOS. Director of the Department of Transportation.

Senator CARPER. All right. I want to start out with a question for the whole panel, but I will just start off with you, if I could.

Recent studies from the University of Michigan and Ford Motor Company suggest that adding AV equipment to cars adds weight, aerodynamic drag, and electrical power consumption that internally increase to fuel consumption. Because AVs could both reduce the cost and increase the availability of driving that could induce greater demand and increased vehicle usage, we may have more vehicles on our roads. We talked about that earlier. Empty vehicles circling city blocks and riders opting for longer commutes.

With on road mobile source emissions already the largest source of greenhouse gas emissions, in our economy, are you concerned that widespread autonomous vehicle deployment may actually worsen this problem? Would you agree that we need more data about how these vehicles will be used in the real world to better inform our understanding of the role that autonomous vehicles will play in transportation sector greenhouse gas emissions?

Mr. PANOS. With regards to the idea that we need more research dollars and more focus on deployment of connected and autonomous vehicles throughout the United States and the various environments—some of them represented by some of my colleagues here today—I would say yes, that we do need to invest more research dollars, and already have. The collaborations between the USDOT and AASHTO, the collaborations between the industry and government have been robust, but need to continue. And the investments in infrastructure research for connected and autonomous vehicles need to continue.

Senator CARPER. All right.

Shailen.

Mr. BHATT. Senator, I began my career trying to reduce single occupant vehicle trips, trying to get people into high occupancy vehicles. The idea that we would have zero occupancy vehicle trips with fleets of autonomous vehicles circling without anybody in them is antithetical to intelligent mobility, so I think we would want to make sure, in working with States and local partners, to make sure that that was not an outcome that we got.

And your point, I think, is well taken on the increased fuel consumption. We haven't spoken as much about it today, but I think a great belief, at least globally, is that the future of mobility also includes a great deal of electrification of the fleet, and that will be something that will help with some of the emission issues.

Senator CARPER. That is a good point. Good point. Thank you.

Is it Dr. Doerzaph? Thank you. Same question.

Mr. DOERZAPH. I am going to echo what both of them said. Some of that is also a sign, I think, of the current maturity of the industry. Sensor racks are hanging off the cars because we are taking legacy cars and retrofitting them. As we move toward vehicles which are designed for automation, some of the aerodynamic drag

aspects will fall away. Some of the weight will probably fall away, as well, as those systems are optimized.

And then, mostly, I would just echo that, yes, zero passenger vehicles should be minimized. If we are going to really have a profound impact on congestion, we need to double or triple or better on every vehicle.

Senator CARPER. All right, thanks.

Commissioner Trottenberg.

Ms. TROTTENBERG. I think you have——

Senator CARPER. Was Iris Schumer commissioner?

Ms. TROTTENBERG. Yes, it was Iris.

Senator CARPER. During the Bloomberg administration?

Ms. TROTTENBERG. She was Giuliani and Bloomberg.

Senator CARPER. OK.

Ms. TROTTENBERG. You have asked the key question. Today we are focusing so much, first and foremost, understandably, on is the technology safe, how do we ensure it is safe, but you are really getting to what I think, in urban areas, is the key public policy question. If we deploy this safe technology, and all it does is further congest our streets, I think this will not have been a very successful program.

I think it does bring a lot of policy considerations in, and ones that I will again just make a pitch, localities really need to be part of that process. In New York, we are now seeing Ubers and Lyfts are congesting our streets. They are not no occupant vehicles, but they are one occupant vehicles spending a lot of time cruising in our central business district.

So, we need to both get the technology safe and then grapple with the key public policy parts of this. If we are just adding to the congestion and fuel consumption and emissions, then this technology won't have realized its potential.

Senator CARPER. All right, thank you.

Dr. Kildare.

Mr. KILDARE. Thank you for the question. I believe this actually highlights what everyone has been saying here, that there are a lot of questions around these vehicles and what the implications are going to be, and that is one of Advocates' big points about the issues with the AV START Act, that there is a push toward deregulation and toward preempting some of the States from controlling what is going on with the lack of Federal leadership, a lack of leadership from NHTSA.

We need that coordination between NHTSA and Federal Highway, and we need to be moving toward regulation, not away from it, to making sure that we are going to get the proper results that we are looking for and not have these unintended results that could then compound and cost billions of dollars when it comes to infrastructure improvements that we need to address the problems that are now created.

Senator CARPER. Mr. Chairman, I have two more questions that are fairly short.

A question, if I could, for Dr. Doerzaph. One of the risks that connectivity introduces, the ability to spoof—we talked about this a little bit earlier—spoof, to hack or trick vehicles into behaving in ways they should not, the stop sign into 45 mile speed limit sign,

such as believing a red light is green or a stop sign is a speed limit sign. Research news stories in the California Disengagement Reports have been useful to identify the trouble that automated vehicles have with consistently and correctly identifying traffic lights, bicycles, bridges, pedestrians, animals, and other vehicles.

Given how difficult it is to already maintain our physical infrastructure free of defects, do you believe that we can develop a nationwide physical and digital infrastructure that will be pretty much foolproof, to the point that we can and will safely rely on it?

Mr. DOERZAPH. That is a great question. It gets back to the security by design question that we were talking about earlier, so starting that conversation now and baking it into every aspect of those systems is critical.

I think it is also really important to realize or to think through that, yes, any one subsystem can have a failure, much like humans do. We may see an illusion or hear something that is not actually there, or misrepresent a threat. AV is subject to very similar set of conditions. They are slightly different because their sensors are different, but one of the advantages of AV is that we can have many more sensors.

So, the sensor fusion aspect, where, yes, the vision system sees a sign that is inappropriate, well, that is OK; the mapping system knows the correct. And by the way, it is not just the maps, two maps, it is a local one that is stored and is known to be highly secured, and it has been confirmed by a recently updated map as well.

So, really, the security is multifaceted. There is the aspects of the security which are keeping bad actors from tampering with the systems, but also the aspect of ensuring that what is being perceived by a sensor external to the vehicle is being confirmed by multiple subsystems as well.

So, if that design is appropriately managed, as the evolution occurs, I think it is reasonable to reach a secure system. At the same time, we need to be mindful that the population of hackers and whatnot are bright, and they move with the times as well, so we need to be able to identify those bad actors and successfully remove them from the trust network, which, again, requires a very robust, nationally synchronized, security mechanism.

Senator CARPER. All right, thanks.

Last question I would start with Secretary Bhatt. I don't know if anyone else would like to comment on this question, but if you want to, you are welcome to do that.

The solvency of the Nation's Highway Trust Fund is, as you know, a top concern for our Committee. What are the budgetary implications of enhanced deployment of autonomous vehicles on public roadways and the cost to enable infrastructure to be digitally connected? Are these costs likely to exacerbate the funding challenges that we face already in public agencies on this front? On the flip side, is there a new opportunity to collect mileage based user fees on vehicles that are digitally connected to the infrastructure that they are using?

Mr. BHATT. Senator, thank you for that question. I think that you raise a couple of very important issues. As Director Panos has mentioned, most of the striping and signage that is critical for the

operation of connected autonomous vehicles as we move forward comes out of maintenance budgets, and if you are going to increase your maintenance budget, that is going to obviously impact your construction budget.

And as Commissioner Trottenberg mentioned earlier, the manufacturers need to make sure that they are factoring in the fact that many roads won't be able to be upgraded, given the budget challenges. So, I think that we need to make sure that we invest in technology and in infrastructure, because I think that technology can be used to leverage infrastructure to get more productivity for our economy. I think of it as a global economic competitiveness issue.

I also believe that there has been a lot of discussion over the years; you have led many of the discussions around funding and gas tax issues. Outside of that, I think that the new technology is the best way for us to move to whatever will succeed the gas tax, whether it is a mileage based user fee or VMT or road usage charge, because I think we now have the technology piece that can both be secure and delay some privacy concerns that have been out there, and those are the discussions we need to begin with now.

Senator BARRASSO. Thank you, Senator Carper.

One quick question for Mr. Kildare. Mr. Doerzaph talks about this plethora of sensors that are available, and I think you had talked about the idea of individuals have to go and get an eye exam at the Department of Motor Vehicles, and should each vehicle would independently have to go and get examined to make sure all the sensors are working right, or is it something that would be part of the patenting process when they design that? I am trying to figure out how that all plays into what we are looking at.

Mr. KILDARE. Using the term loosely for AV vision test is establishing requirements for what vehicles need to be able to see and respond to, that we need to design, if we take what we see at the FAA as an example, and we look at either safety the intended function, or we look at functional safety, your product needs to do the things it says it can do, and it needs to not do the things it says it can't do. And making sure that vehicles aren't operated outside of those envelopes are very important.

We had the mention about the sensor fusion, getting sensors to work together. The first part will be can your sensors see that stop sign. Does it know that it is a stop sign? Does it know that it is a stop sign when it has been molested in some way, either in terms of graffiti or art work or bent or—I have been through Texas—shot at? They are used for target practice. There are a lot of changes that can happen out there. We need to establish what are the requirements for whatever that operation is going to be.

We know in the Tesla crash down in Florida, that that vehicle was not supposed to be operating under autopilot on that road, but it was. So how do we do that? What are the requirements we need to establish? If you tell us your vehicle operates only on highways, how do you prove that that vehicle only operates on highways? The same thing for the vision. What does it need to see?

The vision test that we have implies some responsibility on the part of the driver. We ask people to identify a stop sign because they have to stop the vehicle. Now that we are testing the machine,

it has to see the stop sign at all times, and it has to decide to stop the vehicle. That is what we have to require. That is the concern that we have with what we are seeing in the AV START Act, is that we don't see any of these requirements coming up, and we need them.

Senator BARRASSO. I appreciate it.

I appreciate the panel and all your thoughts.

Senator Carper, if you read broadly on this, the technology of where this may go to the issue of these driverless cars circling or do they go someplace else, if they go someplace else, people write about eliminating many parking lots and having an opportunity for actually more buildings in communities.

What does it change in the real estate markets? An article in The Economist this week, under Free Exchange, called "Road Hogs," says economies of scale will push the market for driverless vehicles toward a monopoly.

There are many different components of all of this. They are talking about car dealers no longer going to sell to an individual, but to a fleet, and how does this change the number of vehicles on the market.

I don't know that any of us, if you read enough and different futurists who look at this, it doesn't seem to be that there is a uniform agreement as to where the future may be taking us as this all plays out in time, so I am just very grateful that all of you would take your time today to come here to testify from a variety of backgrounds, but to give us your very best thoughts. I thought it was a very helpful hearing, and I appreciate all of you.

The hearing record is going to remain open for a couple more weeks—actually 2 weeks—so some other members who have been here and haven't had a chance to ask questions may submit written questions to you, so I want to thank you again for your testimony today on this very important issue.

With that, the hearing is adjourned.

[Whereupon, at 11:39 a.m. the Committee was adjourned.]

[Additional material submitted for the record follows:]

Public to U.S. Senate:
Pump the Brakes on Driverless Car Bill

ORC International CARAVAN Public Opinion Poll

July 2018

ADVOCATES FOR HIGHWAY & AUTO SAFETY

Commissioned by Advocates for Highway and Auto Safety

Founded in 1989, Advocates for Highway and Auto Safety (Advocates) is an alliance of public health, safety, and consumer organizations, insurers and insurance agents that promotes highway and auto safety through the adoption of safety laws, policies and regulations. Advocates is a unique coalition dedicated to advancing safer vehicles, safer drivers, and safer roads.

Introduction

According to the federal government, each year motor vehicle crashes kill tens of thousands of people and injure millions more at a cost to society of over $800 billion. According to the latest statistics from the National Highway Traffic Safety Administration (NHTSA), 37,461 people were killed on our nation's roads in 2016. This is an increase of over six percent from 2015.

Advocates has always enthusiastically championed vehicle safety technology and for good reason -- it is one of the most effective strategies for preventing deaths and injuries. NHTSA has estimated that since 1960, over 600,000 lives have been saved by motor vehicle safety technologies. So too are we encouraged that autonomous vehicle (AV) technologies hold tremendous promise to achieve additional safety advances and to decrease the number of motor vehicle crashes, fatalities and injuries. However, selling AVs to the public before they can be safely operated on public roads and without commonsense government oversight and industry accountability is not only reckless and ill-advised, but it will also substantially reduce public confidence in this new technology.

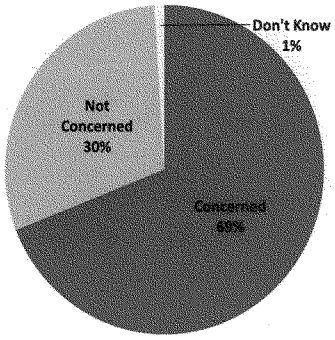
Moreover, there have been a number of crashes involving vehicles equipped with automated driving technology. Those being investigated by the National Transportation Safety Board (NTSB) have file numbers included.

- May 29, 2018, Laguna Beach, CA, Tesla Model S: A Tesla reportedly in "Autopilot" crashed into a parked Laguna Beach Police Department Vehicle. The Tesla driver suffered minor injuries.
- May 8, 2018, Fort Lauderdale, FL, Tesla Model S: The vehicle reportedly was traveling at a high rate of speed when it crashed into a wall. The resulting post-crash fire killed two teenagers and injured another. The NTSB is examining the electric vehicle battery fire and emergency response. (NTSB Investigation HWY18FH013)
- March 23, 2018, Mountain View, CA, Tesla Model X: While on "Autopilot", the vehicle struck a safety barrier, causing the death of the driver. (NTSB Investigation HWY18FH011)
- March 18, 2018, Tempe, AZ, Uber Self-Driving Test Vehicle: The Uber vehicle, which was operating on "self-driving mode," struck and killed a pedestrian walking a bicycle. (NTSB InvestigationHWY18MH010)
- January 22, 2018, Culver City, CA, Tesla Model S: The Tesla, reportedly on "Autopilot," was traveling at 65 mph when it crashed into the back of a parked fire truck that was responding to the scene of a separate crash. Remarkably, neither the driver nor the first responders were injured. (NTSB Investigation HWY18FH004)
- November 8, 2017, Las Vegas, NV, Driverless Shuttle Bus: A driverless shuttle was involved in a crash during its first day of service. Fortunately, there were no deaths or injuries. (NTSB Investigation HWY18FH001)
- May 7, 2016, Williston, FL, Tesla Model S: Driver killed when his vehicle, operating on "Autopilot," crashed into the side of a truck tractor combination, traveling underneath the trailer. (NTSB Investigation HWY16FH018)

The U.S. Senate is considering a bill, the American Vision for Safer Transportation through Revolutionary Technologies (AV START) Act, S. 1885, which will set policy on AVs for decades to come. The bill is awaiting action and could come up at any time. The U.S. House of Representatives passed the Safely Ensuring Lives Future Deployment and Research In Vehicle Evolution (SELF DRIVE) Act, H.R. 3388, on September 6, 2017.

This poll was commissioned to take the pulse of the public regarding if they are concerned about AVs and if they think the findings of the NTSB are relevant to the policy discourse.

The public is overwhelmingly concerned about sharing the road with driverless vehicles as motorists, bicyclists and pedestrians.

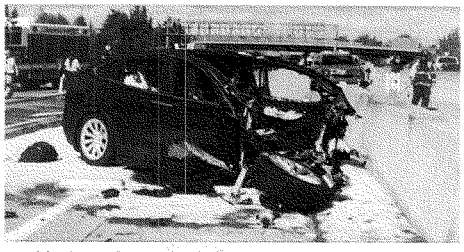


The public has said loud and clear – they are concerned about sharing the road with driverless cars. This apprehension is widespread across demographics including gender, generations, region, education and political affiliation.

Not only will driverless car safety affect those who ride in them, but they will also pose serious risks to other road users including bicyclists and pedestrians.

In order to allay this public skepticism, the U.S. Senate must put in place proper protections to ensure the safe development and deployment of driverless cars.

Give the Nation's preeminent transportation investigatory board time to do its job.

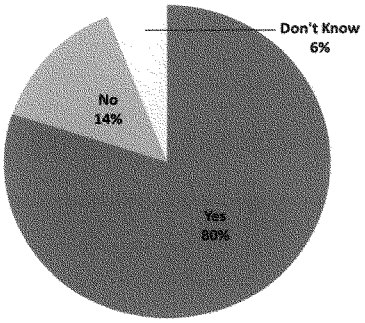


The National Transportation Safety Board (NTSB) is currently investigating several crashes involving cars equipped with self-driving technology. As these investigations are taking place, Congress is considering legislation that would allow the widespread sale of experimental driverless cars. The NTSB is undertaking these investigations to determine how self-driving vehicles interact with the driving environment, other vehicles and vulnerable road users such as pedestrians and bicyclists.

Furthermore, a thorough and independent analysis of these crashes is needed to identify safety deficiencies, determine any contributing causes, and recommend government and industry actions to prevent future deadly incidents. For more than 50 years, NTSB investigations, findings and recommendations have been essential to ensuring the highest safety standards in all modes of transportation in this country.

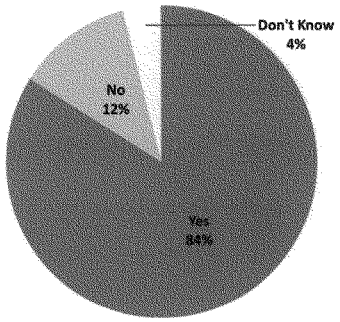
Do you believe the NTSB investigations will be helpful in identifying problems and recommending improvements?

80% say YES



Do you believe the NTSB should complete their current investigations of crashes involving driverless cars before Congress acts on legislation?

84% say YES



There should be no legislative action on driverless car legislation until the NTSB finishes its ongoing investigations into AV crashes and failures.

United States Senate

Committee on Environment and Public Works

Hon. John Barrasso, Chairman

Hon. Thomas R. Carper, Ranking Member

Testimony of:
Mr. Juan Arvizu, Chair
American Traffic Safety Services Association (ATSSA)

June 13, 2018

Chairman Barrasso, Ranking Member Carper and members of the Committee, thank you for the opportunity to submit written testimony on behalf of the American Traffic Safety Services Association (ATSSA). My name is Juan Arvizu, and I serve as ATSSA's Chairman. ATSSA is an international trade association which represents 1,400 members who manufacture, distribute and install roadway safety infrastructure devices such as guardrail/cable barrier, pavement markings, rumble strips, signs and work zone safety devices.

In addition, I am the Chief Operating Officer of a pavement marking company – Pavement Marking, Inc. – based in Tempe, Arizona, offices in El Paso, Texas and Humble, Texas. My company installs and removes pavement markings and rumble strips throughout Arizona and Texas.

I appreciate the Committee holding this hearing focused on emerging autonomous vehicle (AV) technologies and their effects on our nation's roads and bridges. Our industry has an incredibly important role to play with AVs – especially with pavement markings, signs, roadside safety hardware and work zones. The terrifying thought that is constantly on the minds of ATSSA members is that of an AV which doesn't recognize a work zone in its line of traffic, and plows into and kills men and women who are on the road, doing their jobs. While we prepare for the future of surface transportation in the United States, we must ensure that safety continues to be the central focus of our federal transportation policy.

Even with the scenario listed above being a concern, our industry is excited about the prospect of AV technology contributing to the roadway safety ecosystem. As the manufacturers and installers of many of the devices which will be required to communicate with vehicles, our industry is going to be playing a significant role in this next generation of surface transportation.

It is important to remember that although AV technology holds much promise for safety, more than 37,000 men, women, and children were killed on U.S. roads in 2016. This tragedy is occurring today, and we cannot take our eyes off that very real issue. In 2016, the median annual household income in the United States was $59,039. AVs are certainly becoming more and more available to consumers; however, U.S. families most likely will focus their financial resources elsewhere for the foreseeable future, such as on paying the rent and mortgage and monthly bills. Additionally, the median age of the 253 million cars in the U.S. is approximately 11.4 years. Assuming this figure remains somewhat constant in the years ahead, we are still many years away from full deployment of AVs on U.S. roads. We should use this time to work together to ensure that our roadway infrastructure and the public are ready.

This is not to say that we are pessimists when it comes to this technology, but rather realists. As Congress continues to debate the autonomous vehicle issue, Congress must not shirk its duty to maintain and enhance safety for the average road user. We must increase our investments for proven, life-saving countermeasures which will enhance safety for both human drivers and autonomous vehicles. Countermeasures such as wider and more retroreflective pavement markings and adequate traffic signs are two such examples. As the roadway safety infrastructure industry, we also need auto manufacturers to provide us their needs and requirements as it relates to infrastructure.

At the end of the day, a lot of this conversation boils down to funding. Funding for today's roadway infrastructure and the roads that we need for tomorrow's vehicles. It will not be cheap. There are more than 4 million miles of roads in the United States. Many of which are lacking basic countermeasures

such as pavement markings, proper signage and guardrail. Before full AV deployment, we must consider how an AV will handle unmarked and poorly signed roads as well as unpaved roads – especially in rural areas.

Congress has yet to determine how to ensure the solvency of the Highway Trust Fund. We are approaching a critical juncture for funding for surface transportation. As we start adding investments to address the needs of AVs, this funding issue will only be exacerbated. We call on Congress to raise user fees for the Highway Trust Fund to ensure that we have the certainty, stability and resources necessary for combating these safety challenges and preparing for future vehicle and infrastructure technologies.

The Senate Transportation Appropriations legislation includes report language directing the Federal Highway Administration (FHWA) to publish a schedule for periodic updates to the Manual on Uniform Traffic Control Devices (MUTCD), specifically indicating that the deployment of AVs will necessitate regular updates to regulations. This is an important step and we are strongly supportive of this language.

Thank you again for the opportunity to submit testimony. We look forward to working with the Committee on roadway safety infrastructure issues in the months ahead.

On behalf of The American Trucking Associations we respectfully submit our comments to the Federal Highway Administration regarding automated driving systems to be included as a part of the record for the hearing on June 13, 2018 titled "Innovation and America's Infrastructure: Examining the Effects of Emerging Autonomous Technologies on America's Roads and Bridges."

With appreciation,

Joseph Hart
Vice President, Legislative Affairs
The American Trucking Associations
202-544-6245

FEDERAL HIGHWAY ADMINISTRATION
U.S. DEPARTMENT OF TRANSPORTATION
DOCKET # FHWA-2017-0049

Request for Information: Automated Driving Systems

SUBMITTED BY:
American Trucking Associations
950 North Glebe Road Suite
210
Arlington, VA 22203

Michael Cammisa
Vice President, Safety Policy, Connectivity & Technology mcammisa@trucking.org

March 1, 2018

The American Trucking Associations (ATA)[1] submits these comments to the Federal Highway Administration (FHWA) on the agency's request for comment on Automated Driving Systems (ADSs) (83 Fed. Reg. 2719).

As the national representative of the trucking industry, ATA has a strong interest in highway safety for all motorists. Highways are the motor carriers' and drivers' workplace. Employing more than 7.3 million people and moving 10.5 billion tons of freight annually, trucking is the industry most responsible for moving America's economy. The trucking industry moves 70.1 percent of our nation's domestic surface freight and is a critical player in the safety of our nation's roadways, spending $9.5 billion per year on safety training, technology, equipment, and management.

Automated and connected vehicle technologies have the potential to dramatically impact nearly all aspects of the trucking industry. These technologies can bring benefits in the areas of safety, environment, productivity, efficiency, and driver health and wellness. Automated driving technology is the next step in the evolution of the safety technology currently available, and will help to further improve driver safety and productivity, as well as the safety of other motorists and road users. Automated technology comes in many levels that will assist the driver and in some cases, handle the driving task.

[1] ATA is a united federation of motor carriers, state trucking associations, and national trucking conferences created to promote and protect the interests of the trucking industry. Directly and through its affiliated organizations, ATA encompasses over 34,000 motor carriers and suppliers of every type and class of operation in the United States, Canada, and Mexico.

The application of automated and connected vehicle technology in the trucking industry will center on solutions in which there remains a role for drivers, recognizing the duties and requirements drivers have beyond operating the vehicle.

As noted in our comments filed with NHTSA in November 2017 regarding Automated Driving Systems 2.0: A Vision for Safety, from the trucking industry perspective, the role of the federal government in leading the deployment of autonomous technologies is essential. Our industry relies on an interstate highway system that facilitates the free flow of goods between the states, and continued investment in roadway infrastructure is crucial. ATA makes the following recommendations regarding infrastructure to foster innovation and enable deployment of automated and connected technologies to meet the diverse needs of the trucking industry:

- Investments in infrastructure such as repairing, maintaining, and improving pavement, lane markings and signs as well as intelligent transportation systems (ITS) technology will benefit both automated and conventional vehicles.
- The 5.9GHz DSRC spectrum, including all seven of the allocated channels, should be protected for Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and related applications (collectively referred to as V2X). The FCC should not allow sharing of this spectrum for other uses (such as WiFi).
- Appropriate agencies should consider equipping Emergency Services (e.g., police, fire, rescue) and roadway construction sites (including equipment, vehicles, and workers), with V2X communications capabilities so that they can be more fully integrated into a connected driving environment.
- The trucking industry should continue to work with the federal government to enhance a vehicle-to-vehicle "Basic Safety Message" (BSM) standard that meets the needs of all vehicles, especially combination vehicles. Exchanging BSMs among vehicles can improve safety of all road users by providing V2V-equipped vehicles and drivers with safety-critical information about surrounding vehicles including, but not limited to, vehicle position, speed, size, and configuration.

Conclusion

ATA supports the development of automated vehicle technology for all vehicle types. This technology has the potential for improving safety, the environment, reducing congestion, and saving fuel. ATA is pleased that the Department of Transportation is engaging relevant modal administrations – including FHWA, FMCSA, and NHTSA – to prepare for the introduction of innovative technologies such as ADS. ATA encourages FHWA to continue to engage with the trucking industry and other stakeholders to understand the potential infrastructure requirements for all road users as ADS technology is developed and deployed.

The Center for
Auto Safety
1825 Connecticut Ave. NW Suite 330 Washington, DC 20009
www.autosafety.org

June 13, 2018

Chairman John A. Barrasso
U.S. Senate Committee on Environment
and Public Works
410 Dirksen Senate Office Building
Washington, DC 20510

Ranking Member Tom Carper
U.S. Senate Committee on Environment
and Public Works
410 Dirksen Senate Office Building
Washington, DC 20510

RE: Hearing on Innovation and America's Infrastructure: Examining the Effects of Emerging Autonomous Technologies on America's Roads and Bridges

Dear Chairman Barrasso and Ranking Member Carper:

The Center for Auto Safety ("the Center") wants to express our appreciation for the Committee holding this important hearing today. Despite the ceaseless hype and hyperbole by some industries and investors interested in short term profits, the era of driverless vehicles is in its infancy. Accordingly, this is exactly the moment to conduct a holistic review of the future these technologies and examine how to ensure it coincides with the maintenance of our existing roads and bridges as well as any new projects. How and when our nation's infrastructure will be prepared to accommodate autonomous technologies for passenger and commercial traffic is a question best answered in concert with – and not separate from – the legal, regulatory, and safety issues that surround these early developmental days for driverless cars and trucks. Such a potentially revolutionary change requires careful planning at the local and national level and is unlikely to be best served from a rush-to-market philosophy.

The Center, founded in 1970, is an independent, non-profit consumer advocacy organization dedicated to improving vehicle safety, quality, and fuel economy not only for our members, but all drivers, passengers, and pedestrians in rural and urban areas alike. On behalf of those 310 million Americans who use our nation's roads and bridges daily, we urge the Committee to recognize that it may be decades until deployment of truly autonomous passenger vehicles is realized at levels beyond small geofenced areas. Therefore, while driverless cars may represent an exciting future, and generate headlines, in the here and now Americans are buying twice as many *used* cars and trucks every year instead of the technically advanced new vehicles. The annual death toll of 37,000, and more than 2 million serious injuries, from traffic crashes will not be waved away by a magic wand called "autonomy" any time soon, because conventional vehicles will dominate our roadways for decades to come. Our infrastructure plans should bear this in mind.

V2X

Vehicle-to-Vehicle, (V2V) Vehicle to Infrastructure, (V2I) Vehicle to Pedestrians, (V2P) and Vehicle to Network, (V2N) technology is often referred to collectively as "V2X." This connectivity has the potential to significantly improve traffic safety by giving drivers an early warning of yet-unseen crash hazards posed by other vehicles. V2X could enable drivers to obtain advance warning of other potential road hazards, and could improve pedestrian and cyclist safety as well. Such communication has the potential to make everyone's lives more efficient and convenient. For example, V2I and V2N could allow for an offramp's traffic camera to inform a vehicle's GPS of backed-up traffic and offer a reroute that gets the vehicle's occupant to her destination more quickly and with the use of less fuel or electricity. Put simply, V2X has great potential for safety advancements if it is an integrated feature of driverless vehicle and infrastructure development – and not an after the fact add-on.

Yet, it is exactly this integration that presents significant challenges in developing and implementing effective and reliable V2X communications systems, and in taking them from the closed testing environment to the open road. These include technological challenges, such as message congestion and gaps in GPS coverage; security challenges, such as vulnerability to hacking; and potential privacy issues.[1] In other words, for V2X to be a successful feature – and not simply a luxury infotainment system – it will require the intervention of regulating bodies, be they Congress or the Department of Transportation.

To begin with, all new vehicles will need have V2V and V2I as a standard feature, because the value of the connectivity is in its ubiquity. Also, V2X must have a common language, not only from manufacturer to manufacturer, but from state to state, and even city to city. Finally, safety messaging and traffic information must be separate from and primary to infotainment. This is important not only from a cybersecurity standpoint, but from a primacy of purpose view as well. Dedicated Short- Range Communication (DSRC) can accomplish this last item right away.

The Center maintains that moving forward with a safety focused DSRC rule that maximizes the spectrum previously set aside for this purpose, as contemplated by the V2V rulemaking undertaken in January 2017 by DOT,[2] is the fastest way to get this lifesaving technology deployed on today's vehicles. Unfortunately, that rulemaking has come to a complete halt because of what appear to be commercial interests advocating for technologies that could prioritize entertainment over safety. After a complete review it may well be that DSRC can be improved upon when it comes to delivering on the potential for connected vehicles and roads in terms of both safety and economic utility. Yet, instead of having that debate on the way to a safety rule, the process to require V2V communications has been ground to a halt with no movement in sight. It is exactly this kind of conflicting motive that can only be overcome by a nationwide plan that builds safety into the infrastructure from the start.

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[1] Yet another reason using Dedicated Short- Range Communication is a good idea. https://consumerfed.org/press_release/consumer-auto-safety-groups-call-non-commerical-use-auto-safety-spectrum-strong-privacy-security-protections/

[2] https://www.regulations.gov/document?D=NHTSA-2016-0126-0009

Cybersecurity

As discussed above, the measured and planned development of V2X technologies are likely to play a key role in the success of driverless vehicles achieving their maximum utility from both a safety and commercial standpoint. V2X technologies have the potential to dramatically improve highway safety and traffic situational awareness for both conventional and driverless vehicles.

Unfortunately, these technologies also provide multiple opportunities for bad actors to interfere with individual vehicle operation, and potentially interfere with operation of the entire transportation system. The presence of safety-critical software in conventional automobiles (SAE autonomy levels 0-2) and the complete dependence of driverless vehicles (SAE autonomy levels 3-5) on extensive safety-critical software demand the establishment and enforcement of software safety standards for all elements of the technology. The reliance on safety critical software is what led the Department of Defense[3] and the Federal Aviation Administration (FAA)[4] to recognize the absolute need for cybersecurity in these types of applications and to respond by promulgating enabling requirements and regulations. These guidelines have been successful in protecting the security of military assets and the public safety of commercial aircraft operations.

While fully driverless vehicles may be years away from widescale deployment, or public acceptance, the time to plan for such occurrences is prior to their arrival. This is especially the case when it comes to the difficult and time-consuming task of creating usable process and performance standards for the cybersecurity of the hundreds of millions of driverless vehicles that may one day be operating across the country. Unfortunately, neither of the major bills currently under consideration in Congress regarding driverless vehicle technology require cybersecurity standards – either for the vehicles or infrastructure. What makes this lack of standards particularly puzzling is that analogous standards exist, such as RTCA DO-178C,[5] which are required to be met by the FAA prior to aircraft certification and commercial use.

As has been demonstrated in the of context a moving vehicle, the threats of cyber intrusion for autonomous cars and trucks are real.[6] Moreover, at a moment when massive

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[3] DOD 5000.02, January 7, 2015, section 3h, Information Technology;

"(1) All IT that receives, processes, stores, displays, or transmits DoD information will be acquired, configured, operated, maintained, and disposed of consistent with applicable DoD cybersecurity policies, standards, and architectures.

"(2) Risks associated with global sourcing and distribution, weaknesses or flaws inherent in the IT, and vulnerabilities introduced through faulty design, configuration, or use will be managed, mitigated, and monitored as appropriate.

"(3) Cybersecurity requirements must be identified and included throughout the lifecycle of systems including acquisition, design, development, developmental testing, operational testing, integration, implementation, operation, upgrade, or replacement of all DoD IT supporting DoD tasks and missions."

[4] FAA Advisory Circular AC No. 20-115C, Subject: Airborne Software Assurance, specifies acceptability of RTCA DO-178C, "Software Considerations in Airborne Systems and Equipment Certification," dated December 13, 2011.

[5] https://www.faa.gov/aircraft/air_cert/design_approvals/air_software/

[6] https://www.wired.com/2015/07/hackers-remotely-kill-jeep-highway/

cyber-breaches of major corporations or government entities seem to be announced on a weekly basis, to undertake the mass deployment of hackable multi-ton vehicles that can travel 100 mph without mandatory, demonstrable, security protocols is not only foolhardy – it presents a potential national security concern. The time is now to determine whether it is better to use an existing standard and adapt it to the ground transportation needs for V2X, or whether a new protocol must be developed.

Finally, from a fiduciary perspective, addressing these issues and implementing solutions on the front end is likely to be far less expensive than attempting to close the barn door after the proverbial horses have already escaped. All of us who believe in the importance of auto safety must work together to encourage the development of safety-critical software requirements or regulations in response to these emerging threats in order to mitigate, and ideally eliminate, automotive vehicle and related infrastructure cyber vulnerabilities.

Crash Data

As recent on-road crashes involving semi-autonomous (level 2) vehicles have demonstrated, the interaction between infrastructure and next generation vehicle technology can have tragic consequences.[7] In fact, the Tesla operating on "Autopilot" in the fatal Mountain View, California crash was reported to have veered into a guardrail – in a spot it had done so previously.[8] In another instance, Tesla had two separate vehicles using the "Autopilot," mode crash in essentially the same highway location approximately one year apart.[9]

One of the key issues raised in any crash involving cars with autonomous or semi-autonomous technology, including the one involving an Uber that killed a pedestrian in Tempe, Arizona, is how to understand what happened.[10] Two of these incidents resulted in deaths, two involved injuries. Ideally, each crash helps prevent the next one, but after each of these incidents there were conflicting media reports, and in some instances, conflicting police reports. How can national policy makers and the public be sure they are getting the facts? How can local authorities understand whether the infrastructure is to blame or the vehicle is at fault?

Today, when the National Transportation Safety Board (NTSB) undertakes a crash investigation of semi-autonomous vehicles, the agency has to work with manufacturers to access any data available to assist in an accurate evaluation of the crash. Unlike aviation, railroad, and ship accidents, when it comes to driverless vehicles, investigators are dependent upon the manufacturer to interpret the data and provide an accurate account of all relevant data available to the vehicle's recording systems.

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[7] Drew Harwell, Experts Worry Tesla is using consumers as guinea pigs, Washington Post, June 11, 2018

[8] http://abc7news.com/automotive/i-team-exclusive-victim-who-died-in-tesla-crash-had-complained-about-autopilot/3275600/

[9] https://www.upi.com/Self-driving-Tesla-car-crashes-in-same-California-location-as-2017-accident/1131527692147/

[10] Uber – Tempe, AZ, March 18, 2018, resulting in a death; Tesla – Mountain View, CA, March 23, 2018, resulting in a death; Waymo – Chandler, AZ, May 4, 2018, resulting in an injury to the test driver; Tesla – South Jordan, UT, May 11, 2018, resulting in an injury to the driver.

Yet, there are no uniform parameters for driverless vehicle data recorders to allow crash investigators to compare information across manufacturers to help understand whether different autonomous systems might react the same or differently to the same stretch of road. Making things even more difficult in the context of several of these incidents, the manufacturers publicly disclosed information about the crash, prior to any official announcements, thwarting long-established policies of cooperation that are critical to conducting independent crash investigations.

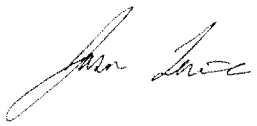
Current event data recorder (EDR) requirements focus exclusively on the milliseconds prior to a crash with enough impact to cause airbags to deploy (among other factors). To properly evaluate driverless technology, investigators must be able to see far more time and data than on conventional vehicles. They must have access to pre-crash and post-crash data to be able to accurately evaluate the performance of the driverless vehicle. Otherwise, it will be next to impossible to answer such questions as whether a sensor malfunctioned or was simply not good enough; whether there was a data processing, communications, or software problem; whether a safety driver or the machine was in control; or whether the fault lies with a conventional driver. Current EDR rules mean the public and policy makers will have to rely on the *least* objective party involved to provide the information: the manufacturer. As the Committee with jurisdiction over public roads, highways, and bridges, it is vital for your oversight purposes to be sure that enough objective, unbiased information will be available to crash analysts to reduce or eliminate unnecessary deaths, injuries, and property damage.

Conclusion

While it is our current position that driverless cars should remain on test tracks and in controlled environments until they have demonstrated sufficient levels of safety to be allowed into our neighborhoods, it is our hope that this will not always be the case. At some point in the coming decades, driverless vehicles are likely to be deployed on public roads. These vehicles and infrastructure must work together to maximize safety for everyone on the road. Undertaking that process simultaneously is the best chance for all of us to reach that future as safely as possible.

On behalf of the Center for Auto Safety and our members, thank you for your attention to this important matter.

Sincerely,



Jason Levine
Executive Director

June 13, 2018

The Honorable John A. Barrasso, Chairman
The Honorable Tom R. Carper, Ranking Member
Committee on Environment & Public Works
U.S. Senate
Washington, DC 20510

Dear Chairman Barrasso and Ranking Member Carper,

Thank you for holding a hearing to examine the effect of autonomous technologies on America's infrastructure. We are safety and consumer organizations that have worked for many decades to reduce highway crashes and improve auto and truck safety. We endorse the testimony of Shaun Kildare of Advocates for Highway and Auto Safety in its entirety, including the conclusion that upgrades are needed to American infrastructure for the safe deployment of autonomous vehicles.

We write today to express our deep concerns that autonomous vehicles are being placed on our nation's roadways without sufficient assurances that they are safe. We are particularly concerned about the AV START Act (S. 1885), currently pending in the Senate, because it lacks adequate public safeguards to ensure the safety of autonomous vehicles. Before autonomous vehicles are allowed to be deployed on the nation's roads, there must be proper government oversight and industry accountability to protect the public. While we are hopeful that in the future driverless cars may result in significant reductions in motor vehicle crashes, deaths and injuries, we are very concerned that provisions in the bill put others sharing the road with AVs at unnecessary and unacceptable risk. The recent crashes and fatalities involving autonomous vehicles illustrate the grave risks of employing this new technology before it is ready.

Our concerns mirror those that are discussed in Dr. Kildare's written testimony, and they include:

- **The size and scope of exemptions from federal safety standards must be considerably narrowed.** The AV START Act would allow for potentially millions of unproven AVs to be exempt from current federal motor vehicle safety standards (FMVSS) and sold to the public. The number of AVs that will be permitted to be exempt from FMVSS should be reduced and the time period between exemption "tiers" should be extended to allow for adequate time to assess the real-world impact on the road safety performance of exempt vehicles. Further, any exemption from FMVSS that would diminish the current level of occupant protection should be prohibited. Moreover, manufacturers must not have unfettered discretion to unilaterally make safety systems inoperable.
- **The Safety Evaluation Report (SER) prepared by manufacturers must contain sufficiently detailed information to provide NHTSA with all necessary data and information.** This information should include testing protocols, on-road performance, crashworthiness, data recording and cybersecurity protections.
- **Minimum performance requirements must be set to address critical issues with AVs.** Significant safety vulnerabilities need to be addressed through basic safety rules,

and the AV START Act should direct NHTSA to issue standards for vision testing, cybersecurity, electronics, and driver distraction and engagement. Additionally, the provision which allows manufacturers to disconnect steering wheels, brakes and other safety systems in autonomous mode without any government review and approval must be removed.

- **Consumers need basic safety information about AVs.** As driverless vehicles are sold to the public, it is necessary that consumers know what they can, and cannot, do. Further, consumers must know from which vehicle safety standards their vehicle may be exempt. NHTSA should also be directed to establish a website that the public can use to find out safety information about AVs. And, all crashes involving an AV should be reported to NHTSA and that data should be made publicly available.
- **The varying needs of disabilities communities must be addressed.** Though AVs are often touted as a panacea for mobility issues facing disability communities, they are certainly not a one-size fits all solution. Specifically, there is nothing in the AV START Act that would remove barriers to wheelchair users such as cost or vehicle design. Moreover, in the event of a crash or malfunction, people with certain disabilities may be particularly vulnerable.
- **Require event data recorders (EDRs) on all AVs.** EDRs capture comprehensive crash data in a format that will aid investigations such as those done by NHTSA and the NTSB and result in improved vehicle designs and possible safety recalls.
- **SAE level 2 vehicles must be subject to all safety critical provisions.** A number of the recent horrific AV crashes have involved level 2 vehicles. During the NTSB's September 2017 hearing on the fatal 2016 AV crash in Florida, the Board found deadly failures of the Tesla's level 2 "autopilot" as well as similar problems in other level 2 AVs by other manufacturers.
- **States should not be preempted from acting to protect their citizens.** The bill would preclude states from undertaking regulatory action even though the federal government has not yet done so. This is an unprecedented approach to preemption that should be rejected. Until U.S. DOT issues standards and regulations, states must retain their traditional legal authority to maintain public safety.

Public opinion polls consistently show that concerns about AV safety are widespread and deeply held. In addition, we know that the National Transportation Safety Board is currently investigating the serious crashes that have occurred involving AVs. Congress should wait until these investigations are concluded before passing legislation that would open the door for additional AV deployment on the nation's roadways. It is imperative that any federal legislation encouraging further deployment include safety measures that are based on science and actual experience.

Thank you, again, for your interest in autonomous vehicle technology. We ask you to place this letter into the record of today's hearing. We look forward to working with you to ensure our nation's infrastructure is fully prepared to provide for the safe deployment of AVs, and we hope you will work with us to improve the AV START bill for the benefit and protection of the public.

Sincerely,

Joan Claybrook
Former NHTSA Administrator
Chair, CRASH

Sally Greenberg
Executive Director, National Consumers League

Rosemary Shahan
President, Consumers for Auto Reliability and Safety

cc: Members of the Committee on the Environment and Public Works

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Adopted June 11, 2018 by USCM Membership

Support Proposed Amendments to the "AV START Act"

WHEREAS, highly automated vehicles (HAVs) have become more prevalent and are being tested in more localities; and

WHEREAS, HAVs have been involved in crashes on public roadways, one of which involved and caused the death of a pedestrian; and

WHEREAS, there have been reports that some HAVs have not operated appropriately during heavy snow falls and other inclement weather conditions; and

WHEREAS, localities are charged with reducing traffic crashes and the resulting deaths, injuries, and property damage; and

WHEREAS, localities are responsible for adopting and enforcing laws and rules governing the orderly movement of road users on the streets, highways, bikeways and private roads open to public travel in a manner intended to minimize the occurrences of crashes and ensure pedestrian safety, including but not limited to, through the regulation of allowable speed, prohibition on reckless driving, observance of traffic signage and control devices, requirements for use of available lamps and signaling devices, and limitations on the locations of allowable vehicle operations; and

WHEREAS, federal regulatory authorities have not yet set federal motor vehicle safety standards for HAVs and automated driving systems; and

WHEREAS, the AV START Act permits manufacturers to self-certify the veracity and completeness of Safety Evaluation Reports (SERs), and does not empower federal regulatory authorities to conduct independent assessments or prohibit the testing and deployment of HAVs even if an SER is incomplete or otherwise deficient; and

WHEREAS, due to the absence of such federal standards and the lack of a federal enforcement mechanism concerning SERs, it is imperative that federal legislation preserve local authority to adopt, revise, and enforce traffic laws to ensure that HAVs are operating safely and complying with traffic laws as they are tested on public roadways; and

WHEREAS, federal regulatory authorities have not mandated that manufacturers share data from HAVs with localities; and

WHEREAS, localities are responsible for establishing and maintaining safety programs addressing pedestrian safety; law enforcement; traffic control; crash prevention, investigation, record keeping; and emergency services; and

WHEREAS, localities will need data from HAVs to investigate and monitor crashes involving HAVs and any failures of HAVs to recognize and comply with traffic signage and control devices, speed limits, and other traffic laws and rules of the road; and

WHEREAS, localities will need data from HAVs to manage traffic to reduce delay for passengers and freight; and

WHEREAS, due to the absence of federal guidance mandating that manufactures share data concerning HAV crashes and failures to operate safely and comply with traffic laws and rules, and reduce passenger and freight delay, it is imperative that federal legislation mandate said data sharing,

NOW, THEREFORE, BE IT RESOLVED, that The U.S. Conference of Mayors calls on Congress to adopt streamlined policies that encourage the safe and reliable testing and deployment of HAVs on our nation's roads and highways; and

BE IT FURTHER RESOLVED, that such policies must include the following: a preservation of local authority to regulate automated vehicles to ensure their safe operation and compliance with traffic laws; a mandate for the issuance of federal safety standards concerning HAVs and the components thereof within eight years; and a mandate for data sharing with localities.